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Removing a bush, liable to leaf rust, from the crotch of a forest tree where it has taken root

THE BLISTER RUST OF THE WHITE PINES [See page 216]

Mechanical Analogies In Electricity

Artificial Aids to the Understanding of Principles

By Wilson C. Morris, Ph.D.

In the study of mechanics, heat, sound and light we deal with many phenomena that appeal directly to our senses. As a result students entering high school classes in elementary physics have considerable stock in trade. Electricity does not manifest itself to a special sense as do sound and light; but it is known to us by the heat, light, magnetic, chemical and physiological effects which it produces. We define light (physically considered) as an undulatory motion of the proper frequency for stimulating the retina of the eye. Unfortunately this tells us nothing about the real nature of light. Likewise we can define sound as a vibratory motion capable of stimulating the auditory nerve. Such a statement, of course, gives no definite information regarding sound-waves. The fact that we have not an electrical sense is doubtless the reason why certain popular writers often refer to electricity as an "unseen force"—a term too vague to be of any value.

In general the electrical phenomena are so wonderful that the question, "What is electricity?" is one each thinking person asks himself or some one else. Like many another question it is easier asked than answered. One thing is certain, it can't be answered by direct reference to a special sense. Since this is so we try, as it were, to "visualize" electrical phenomena by connecting them up with things which we have learned through the senses. This has led to an extended use of analogies in the study of electricity. It is the purpose of this paper to consider some of these analogies. There are so many of them that it will be impossible to treat them all in one short paper.

The work of the past twenty years, dealing with the nature of matter, X-rays, radioactivity, etc., has led to the conception of the atom as a complex system. This view is now generally accepted. Of course, there is still difference of opinion as to the make-up of the atom. Until a few years ago, J. J. Thomson's view of the atomic structure prevailed; namely, that an atom consists of a relatively large sphere of positive electricity of sufficient charge to just neutralize the negative electrons which revolve about it. With this conception he was able to account for the periodic properties of various chemical elements. More recent work by Rutherford on radioactivity has led to the conception of the "nucleus atom." According to his view an atom consists of a central positively charged core of relatively small dimension about which a number of negative electrons revolve, whose total negative charge is equal to the positive charge of the nucleus.

If we accept the electronic theory an electric current is a convection current—a stream of electrons moving through the space between the atoms or through the atoms themselves. It is the number of electrons per second passing a given cross-section. Good conductors, as silver, copper, etc., are substances possessing a large number of "free electrons."

With this conception of the electric current there are some well-marked analogies between the flow of electricity and the flow of an incompressible fluid. Water, while not wholly incompressible, will answer. (a) Water requires a force to keep it in motion. The electric current ceases when the electromotive force is removed. (b) Flowing water is resisted by friction which increases with the length, smallness in cross-section and roughness of the surface of the pipe. The electric current likewise meets a resistance which depends upon the length, cross-section and material of the circuit. (c) The energy used to overcome the friction of the pipe in water flow is converted into heat. Likewise, owing to resistance, all electric circuits dissipate energy in the form of heat. (d) When water is flowing in a pipe there is a difference of pressure at any two points which depends upon the rate of flow and the friction. Also there is a difference of potential between any two points in an electric circuit which is proportional to the current and the resistance between these points. (e) The law of continuity applies to water flowing in a pipe (assuming there is no leakage). Kirchhoff's first law—the amount of electricity flowing toward a point is equal to the amount flowing from it—is nothing but the law of continuity applied to electric circuits. (f) The direction of flow of water can readily be seen by drifting bodies. One familiar with the fundamentals of electromagnetism knows there is a fixed relation between the direction of flow of the electric current and the direction of deflection of a magnetic needle pivoted near the circuit in which the current flows. The above analogies show such striking similarities that it is no wonder one hears the term "electric fluid"; and, like a material fluid, an electric charge has a granular structure; but, of course, the granules are not molecules but electrically charged particles much smaller than molecules or atoms.

One of the problems in engineering today is the transmission of energy. Two of the well-known ways are by compressed air and by the electric current. On the surface these two methods seem wholly unlike; but a closer study shows them to be somewhat analogous. The analogy becomes more complete if the compressed air, after being used, is not set free but is returned to the air compressor. Under these conditions the same air goes round and round the circuit; but the air itself is neither consumed nor manufactured. Energy is gotten from the air because it comes to the "consumer" at a high pressure and is returned to the compression pump at a lower pressure. The difference in air pressure in the pipes corresponds to the difference in voltage in the electric transmission lines, and it is this potential difference that causes a "flow" of electrons. Hence an electrical generator (battery or dynamo) is a contrivance for producing a difference of "electrical pressure" just as a water pump or an air

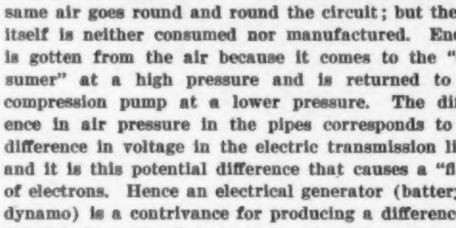


Figure 1

compressor produces a difference in mechanical pressure. Carrying the analogy still further the air particles in the pipe line encounter one another, they also encounter the walls of the pipe and as a result there is some loss due to friction. In a similar fashion, the electrons are held by atoms and encounter atoms, and as a result there is electrical resistance in all circuits. According to modern views in, electropositive elements, such as metals, the atoms have a relatively weak attraction for negative electrons, while in electronegative ones, such as sulfur, nitrogen, etc., the attraction is strong. This means plenty of "free electrons" in the metals and very few in the non-metals; hence the marked difference in electrical conduction in metals and non-metals.

Ohm's law is one of the best-known statements in electricity. For direct currents it is very simple; the current in a circuit or any part of it being directly proportional to the potential difference and inversely proportional to the resistance. Is there a mechanical analogy? Consider a boat moving slowly through water. Since the boat is moving slowly we may assume that the force necessary to overcome the resistance of the water is proportional to the speed. If F pounds of force produce a speed of v feet per second then $F = kv$ or $v = F/k$, where k is the force required to produce unit speed (one foot a second). Likewise if R is the voltage required to produce unit current (one ampere), then if E volts produce I amperes, $E = IR$ or I (the current-electrical speed) $= E/R$. The marked similarity in the two equations, $v = F/k$ and $I = E/R$ is at once evident. One difference must be pointed out, however. The simple statement, I is proportional to E/R, is perfectly general for all direct currents in metals and electrolytes. On the other hand, when the speed of a body moving through a fluid becomes considerable, as in a rapidly moving boat or falling raindrop, the force required to overcome the resistance is proportional to the square of the speed; and hence the analogy breaks down.

If there is a close relation between mechanical resistance and electrical resistance, so there is a close relation between inertia and inductance—that quality of a circuit in virtue of which a current of finite value cannot be produced instantaneously by a finite electromotive force even if the resistance of the circuit is negligible. By reason of mass and motion a flywheel, or any other moving body, is a storehouse of energy. If we take a body weighing W pounds at rest and increase its speed to v feet a second an amount of energy equal to $Wv^2/2g$ foot-pounds is stored. Likewise if a current of I amperes flows in a circuit whose inductance is L henries there is stored an amount of energy $= \frac{1}{2}LI^2$ joules.

If a body of mass m has an initial speed u and a *constant* force F acts upon it for t seconds and changes the velocity to v, then $F = mk\,(v - u)/t = mkj$ where k is a proportionality constant whose value depends upon the units chosen and j is written for $(v - u)/t$ (the acceleration or the time-rate of change of velocity). Just as the velocity of a body may change with time, so may the electrical velocity (the current) change with the time; and as we speak of acceleration in feet per second per second so we may speak of electrical acceleration in coulombs per second per second of in amperes per second. If a current in a circuit whose inductance is L henries changes from I_1 amperes to I_2 amperes in t seconds, then E (the average induced voltage) $= L\,(I_2 - I_1)/t = La$ where a is written for the electrical acceleration. Readers familiar with the calculus will prefer instantaneous values, and hence will use dv/dt in place of j and di/dt in place of a.

In elementary mechanics we find problems of this type. A car weighing ten tons is at rest. What tractive force acting for one minute will impart a speed of twenty miles an hour if friction is neglected? Using gravity units, F (the force in pounds) $= \frac{W}{g} \frac{(v - u)}{t}$ where W is the weight in pounds, g is gravitational acceleration, v is the final speed in feet a second, u is the initial speed in feet a second (zero in this problem) and t is the time in seconds. $F = \frac{10 \times 2000 \times 20 \times 5280}{32 \times 3600 \times 60} =$ 305.5 pounds. Here is an analogous problem in electricity. What voltage is impressed upon a circuit whose inductance is half a henry if the current is 8 amperes one-tenth of a second after the key is closed, neglecting the resistance of the circuit? Substituting in the equation $E = \frac{L(I_2 - I_1)}{t}$, we have $E = \frac{1}{2} \times \frac{8}{1} =$ 40 volts.

If the above car runs into an obstacle which stops it in one minute there will be an average pressure of 306 pounds exerted. If the obstacle stops the car in one second, the pressure exerted will be sixty times as much. Likewise if the current in the above circuit dies out in one-tenth of a second the average induced voltage is 40 volts. If it dies out in one-tenth of this time the average induced voltage is ten times as much.

The car being in motion persists in motion as is attested by the fact that it crushes or tends to crush an obstacle that gets in its way. Likewise the electricity being in motion "presists" in motion; and this presistence may be great enough to give rise to a vicious spark—a well-known phenomenon to one who has opened a switch of an electric circuit when a large current is flowing in the circuit. Just as the moving car crushes or tends to crush obstacles in its way so the on-rush of electricity crashes the air and a spark is the result.

One not well versed with elastic properties of a spiral spring and the capacity of an electrical condenser would hardly suspect an analogy between two things seemingly so different. A closer study reveals a striking analogy. If we apply a pull of one pound to a spiral spring it will elongate it a definite amount, depending upon the dimensions and material of the spring, say y feet. The elongation per unit pull we may refer to as the yield-constant of the spring. From Hooke's law if we apply a force of F pounds the yield will be F times as much. If we call the yield l then $l = Fy$ or $F = 1/yl$. If C is the capacity of a condenser (the number of coulombs of electricity displaced through it when a potential difference of one volt is applied), then if E volts are applied Q (the quantity displaced) $= CE$ or $E = 1/C.Q$. A comparison shows that the yield-constant of a spring is the analogue of the capacity of an electrical condenser. If we take a water circuit like that shown in figure 1, we can get

some ideas of the elastic properties of the diaphragm if we measure the pressure required to distort it sufficiently to increase the volume by unity on one side and thereby decrease it by unity on the other side (since water is practically incompressible for small pressures).

In like manner in an electric circuit such as is represented by figure 2, if we knew the electromotive force in volts required to force a unit charge of electricity (one coulomb) into one plate of the condenser and withdraw a unit charge from the other plate we would at once know the capacity of the condenser in farads, for in the equation $E=1/C.Q$, E is known and Q is unity. Referring to figure 1 again, we see that the force of the piston must overcome the resistance of the water against the walls of the pipe, the inertia of the water and the reaction of the elastic diaphragm. In a similar manner in figure 2, the alternating current generator has to overcome the electric resistance of the circuit, the inductive reactance and the capacity reactance of the circuit.

Consider a simple case of motion, as a *slowly moving* boat, in which both friction and inertia are evident; then the force applied to the boat must do two things, overcome friction and overcome inertia. This is expressed mathematically thus: $F=m\frac{dv}{dt}+kv$, where m is the mass of the boat, v is the velocity, dv/dt is the acceleration and k is a frictional coefficient. In much the same manner take a circuit of resistance R ohms and inductance L henries and impress upon it an electromotive force E volts. Part of this electromotive force will be used to overcome the electric

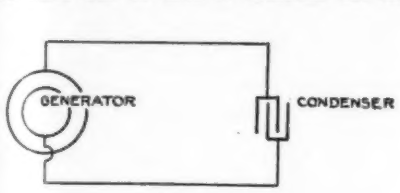


Figure 2

resistance. The amount required for this is Ri if i is the current flowing. Another part will be used to change (increase) the current or the electric velocity. The amount of this component is $L\frac{di}{dt}$ where di/dt is the "electric acceleration" (the time-rate of change of the current). In mathematical language $E=Ri+L\frac{di}{dt}$.

From the first equation we can find the speed of the boat at any instant. In the second the value of the current at any instant can be obtained. The solution of the second equation (Helmholtz's well-known equation) is $i=I(1-e^{-t/T})$ where I (the maximum current) $=E/R$. It is the value of the current when it has reached a steady state; that is, when di/dt is zero, e is the well-known Napierian base, t is the current at a time t, and $T=L/R$ (the so-called time constant). In like manner the solution of the equation for the boat's motion is $v=V(1-e^{-t/T})$, where v is the speed at any time t; and V (the maximum speed) $=F/k$. It is the speed when a steady state has been reached; that is, when dv/dt is zero. T is written for m/k. It may be referred to as the "time constant."

To a nail in a wall fasten one end of a spring whose yield-constant (the elongation per unit pound of force) is y. To the other end fasten a body of mass m. The weight of the body W will now do three things—stretch the spring, accelerate the body and overcome the friction between the body and the wall. If W is the weight of the body (the weight of the spring being negligible), then $W=1/y\ l+kv+mj$. The terms have the same meaning as was assigned to them when formerly used. Likewise if E volts are impressed upon a circuit whose capacity is C farads, whose inductance is L henries and whose resistance is R ohms then $E=Q/C+Ri+La$, where Q is the quantity of electricity in coulombs, i is the current in amperes, and a is the rate of change of the current (di/dt). The analogy is complete. Fleming in his books on "The Alternating Transformer" and "Wireless Telegraphy" gives various analogies of a like kind to which the reader is referred.

Every-day observation reveals that if we take a body free to vibrate without much friction, as a swing, and apply properly timed impulses, it is only a matter of short time until the body is vibrating with a large amplitude. This phenomenon is referred to as resonance. Readers familiar with alternating currents know that when $2nL=\frac{1}{2nC}$ (n is the frequency and L and C have the usual meaning) we have "electrical resonance." In each case it is a matter of frequency.

The resonance analogy can be carried still further as Drysdale shows. Take a rotating machine—say, a horizontal steam engine—placed on a foundation, and compare it with an alternating current circuit having inductance, capacity and resistance (say, a coil with an iron core joined to a condenser). The machine and its foundation will show some yield which corresponds to the capacity of the electric circuit. The mass of the machine and its foundation corresponds to inductance in the electric circuit and the frictional resistance due to any relative motion of the machine and its foundation corresponds to electrical resistance. Just as in alternating circuits there is one frequency that produces resonance, so in the machine, especially if it is running above normal speed, there is a speed at which the vibration is considerable. If the machine is placed on another foundation where the mass and elastic properties are different the same speed may produce very little vibration. In like manner a frequency that produces resonance in one circuit will not necessarily produce resonance in another circuit in which the resistance, capacity and inductance are different.

The various analogies cited will call forth this question, "To what extent should analogies be used?" As in many other cases there are analogies and analogies. Jastrow in his book, "Facts and Fable in Psychology," intends them to be used with caution as is shown by the following: "All this results from the absurd and unwarranted application of analogies; for analogies, even when appropriate, are little more than suggestive or corroborative of relations or conceptions which owe their main support to other and more sturdy evidence. Analogy under careful supervision may make a useful apprentice, but endless havoc results when the servant plays the part of the master."

Drysdale in his work on "Alternating Currents," a book to which I am greatly indebted, says: "Analogies may often seem of the greatest use in assisting us over the first stages of a subject, and may yet do much harm, by giving us erroneous fundamental ideas which we have to unlearn with difficulty before proceeding to higher stages." He spends several pages in discussing the question, "To what extent are analogies legitimate?" This is not my question; but we do know that many of us in our teaching often attempt to substitute an analogy for an explanation. In teaching electricity to a student of limited attainments in mathematics, mechanical analogies are very valuable aids; but it should be understood that, in general, they are *aids* and not explanations.

Readers desiring to pursue the work further will turn to the work of the masters—Faraday, Maxwell and Kelvin. One familiar with the life of Kelvin knows that one of his big problems, which, by the way, he left unsolved, was to devise a mechanical model of the ether.

Cloud Flying

Personally, I seldom use an instrument as an assistance to piloting. Do not assume that I am sneering at instruments; in fact, as I have stated, there are times when they are a necessity. In fact, I am going to suggest that one instrument be fitted as a standard equipment, an instrument to reduce the risks connected with flying in clouds. It may not generally be known that there have been such a large number of fatal accidents during the last three years entirely due to flying through clouds, and I consider this subject wants going into pretty carefully.

The accidents to which I refer have not been questions of a want of height; the machines, have become hopelessly out of control. I will give you an instance which happened to myself a few weeks ago in the west of England. You will then realize why I consider this is a serious matter requiring particular attention.

I set out on a very cloudy, windy day to do a test climb to 10,000 feet on a late type two-seater. I had so often on previous occasions succeeded quite comfortably in reaching this height in spite of cloudy, overcast days by pushing up through the clouds, usually only a matter of a few minutes, into bright sunlight and the bluest of skies, and after reaching the desired height, coming down again through the clouds, having flown by compass and time.

On this particular day, however, the wind was very gusty, and on reaching 1,200 feet we got into dense rain cloud, but carried on to beyond 5,000 feet, still in the cloud, when the compass apparently began to swing (really it's the machine that begins swinging, not the compass). Efforts to check the compass had the effect of causing it to swing more violently in the other direction.

The air speed then rushed up far beyond normal flying speed; all efforts to pull her up checked her only slightly; then the rudder was tried, back went the air speed to zero; there was an unusual uncanny feeling of being detached from the machine, and I knew her to be literally tumbling about in the clouds. All efforts to settle down again to a straight flight seemed to be unavailing, until we emerged from the cloud very nearly upside down. Assuming control again was then an easy matter.

This sort of thing has happened to me more than once, and, in the Flying Corps vernacular, "it puts the wind up you." And it has happened many times with other pilots. In some cases they emerge from the clouds in a spin, others are known in which the planes have collapsed under the strain of the sudden pull-up from the vertical nose-dive.

A few days ago, a squadron commander told me that on one occasion when in France everything loose in his machine fell out while in a cloud. A week or so ago, on the South Coast, a machine disintegrated in a cloud and the main planes landed half a mile from the fuselage. From my own experience, this is a very unpleasant state of affairs, and in consequence I avoid clouds when possible.

Let us try and examine the cause of this. First of all you must realize that in a cloud you see nothing whatever but your machine around you. There is no fixed point visible. The only means by which you can tell if you are flying in a straight course is by your compass and your air speed. The compass should give you your direction horizontally, your air speed your direction vertically.

The first thing that happens, and very readily too, if windy and bumpy, is that your compass card will begin to move slightly. It really appears to you that the compass was suddenly affected by the cloud, and you are flying straight ahead. How often you hear a pilot say that as soon as he got into a cloud his compass started spinning. The moment the compass starts moving it requires extremely delicate ruddering to get it back to a steady position; in fact, one invariably over-corrects the compass movement, and so the trouble begins.

Once the compass starts on a good swing I have found it nearly an impossibility to get it steady again until out of the cloud. Before your compass starts to move, your machine has already started to turn. You rudder the opposite way to check it, over-correct it, and turn sharper the other way on to a banked turn; then the nose drops and speed goes up. Pulling back your elevator-lever has little or no effect, for if you are banked above an angle of 45 degrees the elevator becomes the rudder. All this occurs without the pilot being in the least bit aware of the position that his machine is taking relative to the ground. The instruments available are of little service once he loses his control.

Of what use is his air speed indicator to him indicating 150 m. p. h. if the machine is on a spinning spiral, and he imagines that he is merely descending too fast on a steep, straight glide? He naturally tries to pull up, but with no effect. The bubble does not help him, as centrifugal force will send that anywhere.

It may be argued that if a stable machine is left alone under these circumstances it will right itself eventually and assume a normal glide. It very likely would if the pilot could steel himself to let it entirely alone, but before it did so it would have to be left to do a sheer vertical nose-dive for some moments, and in these days of big weights and little head resistance one is liable to attempt to pull out too suddenly from the dangerous high rate of speed attained on this dive. What I want to see fitted is an instrument which will show a constant vertical or horizontal line and be independent of centrifugal force.

I have no ideas upon the subject nor suggestions as to how this is to be brought about, unless something in the nature of a small gyroscope driven by an air-screw could be employed in some way to meet the requirements of flying in clouds, but until something is provided so that the pilot can see a fixed line, I think we shall continue to have accidents from this cause.—From a lecture by Captain B. C. Hucks, R.F.C., delivered before the Aeronautical Society, London.

Intensive Fish Breeding in Ponds

The Bureau of Agriculture in France has published a series of bulletins upon the use of ponds for intensive fish breeding. It is calculated that a pond 4 hectares in size in which 1,200 carp fry per year are put, will yield 6,000 francs ($1,200) annually from the sale of carp and 1,500 francs ($300) from eels. From these amounts must be deducted 1,000 francs ($200) for initial cost and 1,500 francs for running expenses.

Experimenting in the bread laboratory of the University of Pittsburgh

The bread laboratory of the University of Kansas

Salt-rising Bread

Raising Dough With Newly Discovered Bacteria

By H. A. Kohman, Senior Fellow of Bread Research, University of Pittsburgh

The history of bread extends over incalculable time, and its origin is quite obscured in the mists of antiquity. The words "bread" and "leaven" receive mention in Genesis and Exodus and other books of the Old Testament, indicating that baking as an art was practiced in remote ages. The early discovery of the leaven process was, without a doubt, purely accidental and may be traced to the fact that in eastern countries a mixture of meal and water, if forgotten for a day, will ferment. This simple way of inciting fermentation, together with the advantages of light bread, soon led to the adoption of the leaven process.

Although leaven was used even in ancient times, bread-making methods remained crude and uncertain, and the nature of fermentation was not understood until recent years. It was the classic work of Pasteur in 1857 that proved, beyond any reasonable doubt, that alcoholic fermentation, such as occurs in ordinary bread, owes its origin to one-celled microscopic plants (yeasts). As the result of this research and others, the manufacture of yeast has become a science, and the old-time leaven has been replaced by the almost perfect product now available. Naturally, the progress in yeast making was followed by revolutions in baking. Yeast has proved to be literally the life of the baking business, and has made it one of the world's great industries.

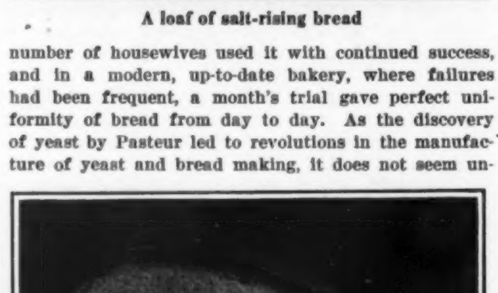
While the method of preparing bread with yeast has been extensively investigated, and the function of this micro-organism in bread is thoroughly understood, salt-rising bread has been peculiarly neglected. If we search the literature upon bread, we shall find volumes upon its preparation by means of yeast—and a mere smattering upon salt-rising methods. Yeast bread is made upon scientific principles, but the methods for the salt-rising type are as crude and uncertain as they were centuries ago! The housewife and the baker still rely upon the old-fashioned "emptins," and to them it is a matter of speculation why these so often fail to "riz." Yet with many people salt-rising bread is the favorite bread. Ex-Governor Stubbs of Kansas is intensely fond of it, and praises its strength-giving powers. He is so fond of this bread that he induced his daughter to learn to make it by promising her a valuable prize should success crown her efforts. At first she met with frequent failures, and at times was counseled to throw a batch out to the chickens.

There is no consensus of opinion in the literature upon salt-rising bread. Most of the writers maintain that the gas formation which aerates this bread owes its origin to "wild" yeasts that accidentally get into the batch from the air or ingredients used. Necessarily, then, it is a matter of chance as to whether the bread will or will not rise, and, indeed, failures are not uncommon. Some writers speak of a spontaneous fermentation and ferments, but do not specify what the germs are.

With the view of putting the preparation of salt-rising bread upon a scientific basis, a thorough investigation was undertaken in the Department of Industrial Research in the University of Kansas, and completed in a similar department in the University of Pittsburgh. In this investigation surprisingly interesting results were obtained. A microscopic study of the "emptins" revealed the fact that it is not yeast at all, as has been maintained, but certain bacteria that raise this bread. From the teeming flora of bacteria that occur in salt-rising dough, it was possible, with extreme difficulty and after many failures, to isolate a bacillus, which by itself can be used in making salt-rising bread. Not only was this baccillus tried in the laboratory, but in the home and bakery as well. A

A loaf of salt-rising bread

number of housewives used it with continued success, and in a modern, up-to-date bakery, where failures had been frequent, a month's trial gave perfect uniformity of bread from day to day. As the discovery of yeast by Pasteur led to revolutions in the manufacture of yeast and bread making, it does not seem un-



Section of a loaf of salt-rising bread

likely that the discovery of this baccillus, which is an exact parallel, will revolutionize the manufacture of salt-rising bread.

The idea of making bread with bacteria need seem neither dangerous nor distasteful. A bacillus may be more "dangerous than a bullet," but not necessarily so. There are good ones and bad ones. Each species is specific in its action. They cause our most dreaded diseases, it is true, but they also make our vinegar, ripen our cheese, flavor our butter and tobacco; and hence no objection can be made to their raising our bread. How does this bacillus differ from yeast? Each consists of small, microscopic cells that must be magnified many times to be visible. Yeast cells are oval-shaped bodies, while the salt-rising bacillus is rod-shaped. The cells of either are independent plants capable of life and reproduction. Yeast multiplies by a process of budding, while the bacilli reproduce by a division of cells known as "fission"; hence the many fission fungi. Reproduction proceeds with surprising rapidity, a cell dividing about every eighteen minutes. From this geometric ratio is has been carefully calculated that if there were sufficient culture media, and growth were not curtailed by prohibitive by-products, the progeny of a single cell would, within a week, literally fill the oceans.

Chemically, this bacillus is easily distinguished from yeast. Yeast, as every one knows, decomposes sugar into carbon dioxide and alcohol, the former of which, owing to its gaseous nature, aerates the bread. Curiously enough, the same chemical changes that aerate bread take place in the production of all alcoholic liquors. The salt-rising bacillus produces no alcohol, and the gas, instead of consisting totally of carbon dioxide, is two-thirds hydrogen and one-third carbon dioxide. Hydrogen is a very light, combustible gas, and in equal quantities will aerate twenty-two times as much bread as carbon dioxide. Owing to its rarity, hydrogen possesses great buoyancy, in consequence of which it is used in filling balloons and dirigibles. It must not be inferred, however, that the lightness of the gas makes proportionally lighter bread. As a matter of fact, salt-rising bread is distinctly solid and close grained, resembling more nearly home-made bread than bakers' bread.

The low density of the gases produced by the salt-rising bacillus, coupled with the fact that no alcohol is produced, has an interesting, economic significance. Scientific research has demonstrated beyond doubt that during the normal fermentation and baking of bread, appreciable losses occur. These losses, which have been estimated to approximate four or five per cent of the total nutrient value of the bread, owe their origin largely to the production of alcohol and carbon dioxide, both of which, on account of their volatility, are lost. In salt-rising bread, these losses are less than one per cent. In consequence of this difference, salt-rising bread is richer and sweeter than yeast bread, for the formation of alcohol and carbon dioxide signify consumption of sugar. This difference of three or four per cent in the bread yield seems a trifling matter when calculated on a bag of flour, but in the aggregate it sums up to a surprising consideration. Calculated on the Kansas wheat crop, for example, the possible saving is sufficient to cover the maintenance of both the university and the agricultural college.

The microbic flora in salt-rising bread may vary greatly. Frequently *Bacillus coli communis* occurs in great numbers in the mass of fermenting dough. This organism, as you know, because of its association with typhoid and other disease germs, renders water unfit for use. Yet the occurrence of this bacillus in bread is no cause for alarm, for it perishes in the oven

Furthermore, there is a sure way to prevent its ever occurring. Whenever the liquid used in setting the "emptins" is brought to a boil, *Bacillus coli communis* will never appear, for it does not form spores and hence perishes in boiling water. The salt-rising bacillus discovered through these experiments, on the other hand, because of its sporulation, withstands this treatment. In the bread, however, even this bacillus, being in the sensitive vegetative state, always perishes in the oven. Hence salt-risiing bread is as sterile as bread made with yeast.

Why eat salt-rising bread? This is a perfectly natural question. Without doubt it is largely a matter of taste. The bread is different. With the first bite one will notice its distinctive odor and flavor, which to many people is decidedly agreeable. Its relative digestibility and wholesomeness remains undetermined. It may be truly said, however, that it is eaten by many with perfect safety, while yeast bread causes indigestion.

This research promises to prove of practical value. Plans are already made by which a leaven, containing the newly discovered bacillus, will be put on the market for home and bakery use. The introduction of this product should eliminate failure and improve the quality of salt-rising bread.

In the meantime if any of my readers desire to make salt-rising bread, they will find the following tried recipe a good one.

RECIPE FOR SALT-RISING BREAD.

Yeast—Take one cupful of sweet milk in a quart cup. Place on stove until milk boils well. Stir into the boiling milk five or six teaspoonfuls of white corn meal, to which a pinch of soda has been added. Wrap up well and set in a warm place over night, or until it is light.

Sponge—Pour one and a fourth cupfuls of water, as hot as the hand can bear, into a bowl, and add about two cupfuls of flour. Then add the yeast from the quart cup, and stir with a spoon until mixed. Place the bowl in a warm place until the sponge rises well, about one to one and a half hours. A good way to keep the sponge warm is to place the bowl in warm water. The water should be at body temperature or warmer.

Dough—Take one and one-fourth cupfuls of hot water (almost boiling) and dissolve in it four teaspoonfuls of sugar, one teaspoonful of salt, two teaspoonfuls of lard and add six or seven cupfuls of flour. Then add the sponge and mix well. Add more flour if necessary to make a rather soft dough. Mold the bread into loaves at once. Put in a warm place to rise, one to one and a half hours, and bake in the usual way.

Salt-rising bread is close grained, and it should not be made as light as other bread.

Some readers may be curious to know why this bread is called "salt-rising" bread. Of course salt has no leavening power. There is no light on this question in literature. The name was probably chosen because the leavening power was not understood, and it was thought that salt, in some mysterious way, caused the rising.

Marching Fractures

By A. Howard Pirie, B.Sc., M.D. Edin., Captain, C.A.M.C.

By a "marching fracture" is meant fracture of a second third, or fourth metatarsal bone, or combination of these, in the right or left foot, caused by marching, and with no history of an accident

This fracture comes under the class of fracture caused by muscular action combined with indirect violence, and is caused by severe prolonged marching.

Case 1.—E. T., age 29. After a march of 29 kilometers in one day his feet were very sore. Next morning his felt "as if they were going to burst." That day he marched 9 kilometers, and had to fall out from the pain in his feet. No history obtainable of any sudden breaking pain. He was flat-footed before joining the army. About three weeks after the day he had to give up after marching 9 kilometers he came to our X ray department, and the X rays showed fracture of the third right metatarsal about its middle, with abundant callus formation.

My attention was called to it by two men coming the same day with the same kind of fracture of a metatarsal bone, and neither of them would admit an accident. The typical history is that after a long march, such as 29 kilometres in one day in full marching order or after 10 kilometres a day for ten days, the patient's feet become very sore, especially when standing up after resting. This indicates that the arch of the foot is giving way. The breaking of a metatarsal bone then takes place while marching. This seems to be Nature's method of making the man lie up, so that the arch of the foot may recover itself. The patient does not know when the fracture takes place as his feet are already so sore from the acute flat-foot. After the fracture takes place he struggles on for a time, but has finally to fall out. He remains with his unit because most of the other men have sore feet too, and there is a stigma attached to a man who falls out because his feet are sore. A time comes—it has been usually about three weeks in our experience—when he has to give up and is sent to hospital.

The X-ray photograph made three weeks after the fracture takes place shows a fractured metatarsal bone with abundant callus. One seldom sees so much callus formed in three weeks as occurs in these fractures. No doubt this is due to movement during walking with the fracture.

The exact cause of a marching fracture seems to be the following. In the normal foot the arch of the foot is so constructed that the bulk of the weight of the body is transmitted through the stout first metatarsal. The next strongest bone is the fifth metatarsal, which takes the next largest share in bearing the weight of the body. By referring to the skeleton one sees that the second metatarsal is the weakest bone, the third and fourth following it in order of strength.

When the arch falls down the weight of the body is distributed more equally to all the metatarsals, but the central ones being in more direct line with the astrangalus get more than their share of the weight, and the second metatarsal being in direct line with the head of the astralagus gets the greatest proportion of the weight of the body. It receives more weight than it is constructed for, and under prolonger strain of long marching, when the soldier is carrying his full equipment, it gives way.

When a person stands on his toes on one foot, the greatest breaking strain is near the head of the metatarsal bones, and this is the position in which the fracture occurs most frequently. It probably occurs when the man rises on to the toes of one foot to make a forward step with the other foot.

Case 2—Pte B., age 19½. Felt severe pain in foot during a long march. Came for X-rays three weeks later. X-rays showed fracture of fourth right metatarsal near the head, with abundant callus.

In four of our cases the fracture occured near the head and in two near the middle of the shaft.

This fracture must be fairly common during the long marches made by our men, as these six cases have come to my notice in a series of 13,000 X-ray negatives.—*The Lancet.*

The Biologic Method of Studying the Properties of Soil

If you are planning to become one of Uncle Sam's agricultural soldiers by buying or renting a piece of land and raising "truck" you will be interested first of all in knowing what your soil is best fitted to raise, for while much may be done to almost any piece of earth by adding the proper fertilizers required by a given crop, it is obviously an expensive proceeding to grow a crop by main force on soil not naturally suited to it.

Since the spontaneous flora, or weeds, if you choose, that spring unsown and flourish untended on idle land, clearly indicate the survival of the fittest they furnish a highly valuable index as to the vegetable species which would best thrive in similar locations. The study of the indications thus offered as to the nature of the earth is known as the biologic method of testing the properties of soils. A note in the French agricultural paper, *Vie agricole et rurale*, by Mr. Coquidé, furnishes some valuable hints upon this topic.

Both chemical and physical indications are sought. Thus, earth where the process of nitrification is very slow, is most suitable for such plants as sedges and ferns. The *leguminosae* or family of peas, beans, peanuts, clover, vetches, etc., possess the power of enriching the soil with atmospheric nitrogen, but they demand phosphoric acid and sulphur. Hence if clover, luzern, and the like are found growing wild, they indicate the presence of these mineral foods. A growth of fleshy or scaly plants such as salt-wort indicates an abundance of salts in the earth.

Comparative richness or sterility of soil, under like conditions of sun, wind, slope of ground, etc., is shown in opulence or poverty of growth. A chemical analysis of plants gathered *on the same date* upon different soils of the same locality will often give an idea of the assimiliability of the various elements in the soil.

As regards physical characteristics it is observable that plants differ greatly as to the fineness or coarseness of the soil they prefer, its porousness, etc.

The mountain spinach and the mulleins are found in coarse grained ground. Very deep soils of mingled ingredients called "mellow" are shown by vegetation with long tap-roots, such as salsifris, shepherd's purse, lotus, knot-grass, scabious, etc., all plants which prefer light calcareous or sandy soils. In wet soils we usually find tall stalks, and a cut foliage such as that of the great cow's pasnip and meadow-sweet.

In dry land the stalk is short, sometimes non-existent (rosaceous development), the leaves small or pointed, waxy or hairy. Under the influence of grazing and trampling the plants of certain humid pasture lands present the same features. The confined environment within which they exist is dry by reason of excessive evaporation. The same thing is true of peaty earth, even though the turf itself is swollen with water. It bears a vegetation known as xerophilous, that is, accommodated to aridity, because the turf demands the moisture for itself.

A comparative examination of the dry weight of the plants of the same locality and harvests of the same date may give an idea of the permanence of vegetative activity and of the richness of the sap. The dry weight attained bears a relation rather to the facility of renewal of the saline solutions than to the richness of these.

An early maturity is evidence of a dry soil which is readily warmed by the sun.

In forming an opinion as to which plants are "bad weeds," it should be remembered that these are not the tall, thick-set annual plants, but low perennials such as dandelion and pilosella, or the stoloniferous plants like rushes and dog's grass. The same thing is true of the plants with hard seeds which preserve their germinative faculty for several years, among which are the plantains, mustard, thistle, and dandelion.

The exotic seeds which are sometimes found mixed with cereals or oleaginous plants are rarely much of a nuisance, since, not being acclimated they tend to die out in a few years.

Heat Treatment of Metals*

The Art of Treating Low and High Carbon Steel with Gaseous Fuel

By W. A. Ehlers

In the following considerations given to the subject of the heat treatment of low- and high-carbon steel, it is the aim of the writer to treat the matter from the view point of practical shop operations, and to eliminate all theoretical discussion as far as possible. It is also assumed that furnaces used for treatment of steels are of the proper design and construction, and that only such fuels are to be used as will produce the best furnace conditions with reference to the character of the furnace atmosphere and control of the temperature.

The human element plays an important role in all heat treating processes. Not only is it important to be well acquainted with the chemical composition of steel and the generation and application of heat, but it is also very essential to know the effect of different temperatures, furnace conditions, and methods of cooling upon the constituents of the steel.

COMPOSITION OF STEELS

Steel is an alloy, a chemical compound of iron and carbon united in varying proportions according to the grade of the steel. It contains about 1 per cent of impurities in the form of manganese, phosphorus, sulphur and silicon. The carbon content varies from about 0.04 of 1 per cent to 2 per cent; the remainder is iron. In addition to the iron, carbon and impurities, some steels contain chromium, tungsten and vanadium, which are added to produce certain results.

Carbon steel is divided into two general classes—low carbon, or machinery steel, and high-carbon, or tool steel. Low-carbon steel is soft, ductile and does not harden readily; on the other hand, high-carbon steel is harder, less ductile and has remarkable hardening power. The strength and utility of steel varies according to the per cent of carbon it contains. The following classification of usage represents good average practice:

Machinery steel contains from 0.04 to 0.15 per cent carbon.

Boiler plate and rivet steel, from 0.15 to 0.38 per cent carbon.

Tires, axles, rails, pistons, from 0.38 to 0.62 per cent carbon.

Cutting tools for soft materials, dies and files, from 0.62 to 0.88 per cent carbon.

Heavy cutting tools, bits, chisels and mandrels, from 0.88 to 1.5 per cent carbon.

As has previously been stated all steels are an alloy of iron and carbon, the chemical combination of which is of great importance in the study of subsequent heat treating processes. The amount of the carbon content has a very pronounced influence upon the structure of the steel, which when placed under the microscope presents a granular appearance. During the cooling process in the manufacture of steel, the carbon content always combines with a definite amount of the iron, to form what is chemically known as carbide of iron. This combination presents a structure or grain of the metal very noticeable under the microscope and is known as cementite. The remainder of the iron free from carbon is called ferrite. Then again the cementite will form a mechanical mixture with the ferrite in which the ferrite and cementite will appear in alternate stratas or layers and this is termed pearlite. The relation between these three compounds is such that all steels very low in carbon are made up almost entirely of ferrite or iron, with a very small per cent of pearlite. As the carbon content is increased the pearlite increases with a corresponding decrease in ferrite, until the steel has reached 0.85 per cent carbon, when the ferrite will disappear and it will be entirely pearlite. After this point, cementite will appear, and a further increase in carbon will cause an increase in cementite with a corresponding decrease in pearlite.

In order that steel may be useful for many mechanical purposes its structure must be changed. In other words, the relation between the ferrite, pearlite and cementite must be different from that found after the steel has cooled in its manufacture. This change is brought about by various methods of heating and cooling. Such changes while interesting to study are too complicated, perhaps, to be described here.

The action of heat upon the pearlite, ferrite or cementite varies according to the percentage of the carbon content, hence according to the relation these substances bear to one another. It causes a transformation of the above constituents, which may easily be seen with the aid of a microscope. Thus the ultimate result, if the metal is heated beyond a certain point, is to form a new constituent known as austentite. Now, if the steel is allowed to cool slowly from the temperature at which this new structure appears, it will go back to the original state in which it occurred before heating. In the slow cooling process, however, there are certain characteristics brought out which are worthy of consideration; the transition taking place after the austentite stage is passed is in the following order—martensite, troostite, osmondite, and sorbite. Each stage denote a correspondinigly softer state of the alloy.

One of the most important points to be given careful attention in all heat treating operations is that of the "*critical range*" of the steel, known as the "upper" and "lower" critical range. These values are not constant, but vary according to the carbon content in the steel. The lower the percentage of carbon the greater the difference between these ranges. As the carbon content increases these two ranges approach one another until at 0.85 per cent carbon they merge into one.

The significance of this characteristic in the steel is that during the period of heating between the lower and upper critical range a transformation is rapidly taking place in the constituents of the steel, which begins at the lower critical range, and is completed at the upper critical range. In steel containing 0.85 per cent carbon, this transformation takes place instantly, while for percentages above this amount the transformation is slow.

It is important, therefore, to understand this characteristic of steel if the best success is to be obtained in all heat treating work. For complete annealing and hardening it is necessary to know the upper critical ranges in order not to exceed that point. Heating and cooling below this limiting temperature will not give full and complete results and exceeding it more than 50 degrees Fahrenheit will likewise produce inferior work, by increasing the granular structure of the steel and thus causing brittleness.

FORGING

There is probably no heat treating operation in use in which the principles of correct heat application are more abused than that of forging. Here again one would conclude from observing the majority of forging fires in operation that speed, not quality, is the aim of the manufacturer. In the majority of the forging work done today, the steel is heated in oil-fired furnaces, the coal and coke fire having been abandoned on account of their slowness and irregular heating of the metal.

One of the greatest faults with modern forging work is found in the desire for rapid heating. Under the action of a very intense heat the steel is made to "run" or drip on the exterior before the interior has become properly soaked. Consequently, there exists a core in the bar which when placed under the hammer does not forge properly. It is very important, in order to obtain the best results, that the work should be heated slowly in a soft, reducing atmosphere. Forging temperature should range from 1,500° F. for high-carbon steel to 1,800° F. for low-carbon steel. But instead of these temperatures, we find more forging being done at a "white heat," which is probably nearer 2,500° F.

High-speed steels for cutting tools should never be forged. It is far more economical to turn down such tools from bar stock if the best product is to be obtained.

After forging, all steels having cutting edges or bearing surfaces should be reheated to a temperature of from 1,400° to 1,500° F. and allowed to cool slowly. After this operation they must be ground in order to remove a thin coating of decarburized iron existing in all hot rolled steel, for this surface, if allowed to remain, will prevent hardening.

ANNEALING

This operation is required for several reasons—to relieve any strain in the material caused by hardening, forging, rolling or punching operations, and also to soften the material so that it may be machined as required. It consists in heating the steel to some predetermined temperature depending upon the result to be accomplished, and slowly cooling.

It is very important to heat the steel uniformly and slowly but not too long. The work must be so placed in the furnace that all parts may become heated evenly, and when it has been heated through to the proper temperature the fire should be cut off immediately. Annealing is thus accomplished by a complete change in the composition of the steel throughout by converting it into an entirely new structure. Then, upon slow cooling, other transactions take place in the structure of the steel, which bring it back to its original constituency.

Low-carbon steel, to be fully annealed, should be heated to about 50° F. above the upper critical temperature of the steel, or from 1,450° to 1,700° F., depending upon the percentage of carbon. The lower the carbon the higher the temperature required. For high-carbon steel the annealing temperature should vary from 1,500°F. for 0.85 per cent carbon, to 1,350° F. for 1.5 per cent carbon. If the temperature is allowed to exceed these limits to any extent the structure of the steel is very much changed, and becomes "burnt."

The heating and cooling operations may be accomplished in several ways:

(1) Where it is desired to keep the furnace in continuous operation the steel may be heated to the proper temperature and then buried in sand, lime or ashes which act as a slow conductor of heat and thus produce a slow cooling.

(2) Very slow cooling may be accomplished by allowing the material to remain in the furnace after the heat has been shut off. This method can only be used where the furnace is of good construction and the air eliminated by sealing the doors and other openings.

(3) Another method of slow cooling is to pack the steel in granulated carbon, charred bone, charred leather, fire-clay, sand or slaked lime, placed in an iron box and heated to the proper temperature and then allowed to entirely cool before being removed from the box.

(4) Bright annealing is desired in many classes of work and may be accomplished as follows: Place the steel in iron boxes and seal them by means of clay or sand to prevent any air entering the box. Screw a small gas pipe into the box at a convenient point and also provide a small hole at the opposite side of the box. Turn gas into the box and the escaping gas will burn at the opening. In this way all the air will be driven from the box and no oxidization of the steel will take place.

(5) Another method of quick annealing may be accomplished by a combination of furnace and air cooling. Heat the steel slowly to a little over the upper critical temperature (1,5° to 1,750° F.) Shut off the heat and allow the steel to air-cool, to a little below the lower critical temperature, but never lower than 700° F. Then reheat the steel to a temperature of about 1,200° to 1,250° F. and then allow it to cool in air or in the furnace. This method produces a very tough steel.

High-carbon steel, when annealed for machining only, need not be heated to a greater temperature than 1,200° F., but if it is desired to relieve the metal of stress produced in forging, etc., the temperature should be maintained at about 1,450° F. with an excess of carbon in the furnace, in other words a reducing atmosphere, to prevent scaling.

HARDENING

The process of hardening is similar to that of annealing except that instead of slow cooling the steel is quenched quickly, which causes it to become hardened. There are, therefore, two important operations in this process to be considered—the rate and ultimate temperature of heating and the method of cooling.

In the hardening operation the same precautions are to be observed as in annealing, *viz.*, heat slowly and uniformly; do not exceed (except slightly) the upper critical temperature of the steel being heated. When the steel has thus been brought to the proper temperature the same transition has taken place as in annealing process, that is, the constituents have been changed into the hard structure known as austentite. Upon being suddenly plunged into water or oil while at this temperature, the rate of cooling is so sudden that there is little if any further change in the structure of the steel and it then takes the form of austenite, or if allowed to cool slightly it may change back to martensite or troostite.

One of the greatest mistakes made in hardening rooms is in attempting to harden steel pieces of any

*Reprinted from *Gas Industry*.

considerable size such as dies in an open coal forge. It must be admitted without argument that such pieces cannot be evenly heated in such fires. Uneven heating will necessarily produce uneven cooling, which in turn will cause uneven strains in the steel, and result in hardening cracks.

Heating steels for ordinary hardening can be accomplished in several ways. The most general practice is to use oven furnaces for such work. When this type of furnace is used for high-speed steel, the work should be pre-heated to about 1,100° F. and then placed in an oven having a slightly reducing flame, and a temperature ranging from 1,800° to 2,400° F., according to the character of the tool. There are, however, some classes of work which can be better handled, perhaps, in a liquid bath consisting of molten lead or salts. Small pieces may be handled better in such a bath. This method will not only give uniform heating, but there is less chance for overheating and oxidation. Lead, however, is expensive and therefore cannot very well be used for large pieces. It offers many disadvantages, such as sticking to the parts immersed, and unless the surface is well covered with charcoal it volatilizes very easily and these fumes are poisonous.

To prevent lead from sticking to the work, cover the tools with a paste made of whiting mixed with alcohol, or dip them in a strong solution of brine.

Heating in salt solutions is very practicable and offers some advantages over lead. Pure table salt may be used, or mixed with chloride of potassium in different proportions and thus almost any predetermined temperature may be obtained. The melting point of the mixture may thus be used as a guide to determine the proper heating temperature.

Barium chloride baths are sometimes used for hardening high-speed cutting tools. Their use, however, has been very much limited on account of the fact that very few operators know enough about handling them to have pronounced success. Barium chloride consists of a salt melting at about 1,625° F. and is usually heated in crucible furnaces. The upkeep cost of such crucibles at the present time makes this method almost prohibitive. One of the great advantages in this method of heating lies in the fact that tools having cutting edges do not suffer from oxidation as in other methods of heating, because on removing the tools from the bath a thin film of the solution adheres to the metal and prevents contact with the air. Work which is to be heated in barium chloride should first be preheated to a temperature of at least 1,000° F. before placing in the bath. Frequently this type of furnace is operated at such a high temperature (over 2,200° F.) that pitting of the steel occurs. This may be avoided by carrying a lower temperature.

The second operation of importance in hardening is the method of quenching. This not only applies to the kind of quenching bath but also to the way the part is handled in the bath.

Cold water, oil and air offer the best means of cooling the steel. Air, however, can only be considered for such work where scaling is of no consequence or where the work can be ground after hardening.

Brine is used where extreme hardness is desired, but unless unusual precaution is taken in having the work heated very uniformly, this method is likely to crack the steel.

Even plain cold water is very severe on the work and like brine may cause trouble on account of cracking. Yet for a great many classes of work this method is preferable. The largest part of the quenching is done in oil baths, particularly for high-carbon steels, and those used in places where the specimen may be subjected to considerable shock. Spring steel, likewise, should be quenched in oil. This method of quenching is not quite so rapid, or as severe as water or brine, yet quick enough to give the proper hardness to almost all work.

Quenching should be done rapidly but uniformly. Tongs for holding the work should have as small grip as possible. Long pieces of steel, including drills and reamers should be quenched with their axes vertical. Where this is impossible, such as in very long, round rods, they should be made to roll into the quenching bath with their long axes horizontal, but they should enter the bath very quickly. Round cutting tools should be immersed with their axes horizontal. Small tools or pieces should be kept in motion when placed in the cooling bath.

For cutting tools, many shops are adopting the so-called "self-hardening" steels. These steels contain a higher percentage of manganese than other steels, and also a small amount of tungsten. They harden when quenched in air, and cutting very hard work they will maintain their hardness even when heated almost to a red heat, which in the case of ordinary steels would cause them to soften.

TEMPERING

This process is defined as an operation for modifying the degree of hardness. In other words, it results in relieving the hardening strains caused by sudden cooling and by another transformation in the structure from the austenite, down through the martensite and into the troostite stage. This removes the brittleness of the steel and produces a hard, yet tough and ductile, specimen.

Like the other heating operations, that of tempering depends largely upon the quality of the steel, and the subsequent use to which it is to be put. These conditions determine not only the temperature to which the work must be heated, but also the method or process employed to impart heat to the metal and the way in which it must be cooled.

Tempering by means of an oil bath is one of the most common methods adopted, and is suitable for most work. It insures uniform heating with no chance to overheat. The work, while cold, should be placed in a pot containing a sufficient quantity of black tempering (mineral) oil and then the temperature of the oil raised to 500° or 600° F.

Lead baths offer another practical method of heating for tempering. These are used generally where temperatures higher than that of mineral oil with a flash point of 600° F. is required. This method also ensures uniform heating and is found to be very desirable for spring steel, cutlery, etc. By using tin in connection with the lead the melting temperature may be changed. About one part tin with two parts lead will produce an alloy with a melting-point of about 420° F. By increasing the lead content, holding the tin the same, the melting-point may be increased to that of the melting-point of pure lead or about 630° F.

Sand tempering is another method made use of in small work. Sand is placed in cast-iron pans heated from beneath, and the work, which is generally contained in wire baskets, is completely buried in the sand. This method gives color to the steel indicating the temperature to which it has been brought in the heating.

Tempering in salt baths is also desirable where temperatures above 600° F. are required. A bath consisting of sodium nitrate and potassium nitrate in the proportion of three parts sodium to one part potassium will give good results with temperatures over 600° F.

Air tempering is used where a quick method is necessary for occasional needs. The work is placed on top of a smooth iron plate, heated from below, and is moved about until the proper tempering color appears.

For certain work where a special color is desired, it is better to heat the material in a revolving drum with an abundance of fresh air, and allow it to air-cool. This method will give a good finish to steel when used for certain purposes.

The human element is of so much moment in the color method of determining proper temperatures that it is doubtful whether very correct results can be obtained in this way. Moreover, since the heat necessarily raises the temperature and consequently changes the color of the exterior of the steel before it reaches the interior, it follows that this method is not suitable for all work, especially where it is necessary to modify the degree of hardness throughout the steel for uniform results.

Quenching becomes necessary in the color method in order to prevent heating beyond the desired point. Tempering in liquid baths will usually eliminate the necessity for quenching and will ensure a thorough heating of the part at the required temperature.

The temperature to which steels should be heated for toughening vary according to the composition of the steel, but for most practical purposes a temperature of not over 1,200° F. is most desirable. In other words heat slowly until the steel begins to show a visible red color in daylight and then allow to cool very slowly.

CASE HARDENING

Case hardening, or case carburizing, as it is sometimes called, is the process of so changing the structure of low-carbon steel as to give it a hard wearing surface with the maximum degree of toughness of the interior or core. This condition in steels is desirable for many operations where plain hardening will not give the results desired. It consists principally of imparting to the surface of the steel a case high in carbon. This is brought about by some carbonizing agent, and then properly quenching it. The condition under which carburization takes place can be better understood if we examine what actually occurs. When steel is raised to a red heat its pores are opened, and under the diffusing action of certain gases, free carbon, which is given off by certain carburizing agents, is made to penetrate the surface of the steel.

By the process of case hardening very low-carbon steel containing from 0.15 to 0.25 per cent carbon may be made to show a surface of from 0.5 to 1.0 per cent carbon.

The carburizing agent may exist in either the solid or gaseous state, and when decomposed it gives up free carbon to the steel. Such materials as wood charcoal, animal bone, hoof, horns, leather and salt are most generally used for such work. There are also many special preparations of case-hardening material on the market which command high prices but which are of no greater value than the materials above mentioned, which may be obtained at a much lower cost.

Pack hardening, as the term implies, consists of placing the steel to be case hardened in a malleable or cast iron box of suitable size with alternate layers of the carburizing material, making sure that the packing material surrounds the steel parts on all sides. Especially should there be from 1 to 2 inches of the material between the steel parts and the side of the box. Long slender pieces should be packed vertically to prevent sagging.

After the boxes are thus filled, they should be covered with an iron plate and the edges sealed with plastic clay to prevent the escape of gases when the material becomes hot.

By careful packing and quenching it is posible to obtain different degrees of hardness in the same piece. For instance, in the manufacture of pliers, it is desirable to have the jaws and cutting edge very hard while the handles should be very tough. This condition may be obtained by placing the pliers in a vertical position with the handles up; then pack the lower part in a high-grade carburizing material gradually weakening in quality toward the top. On quenching, dip the jaw end of the pliers first. The results thus obtained will give a very exceptional grade of tool.

The boxes containing the material to be case hardened should be placed in *uniformly* heated furnaces. Unless the heat is uniform there will be a difference in the pieces turned out. The work should be heated slowly to 1,300° F., and then carried to about 1,800° F.

The time of heating depends upon the depth of penetration desired, the size of the boxes, and the temperature of the furnace. No definite rules can be laid down for this. It must be determined by experiment. A good plan, however, is to insert a number of pieces of 3/16-inch wire in the cover of the box through to the bottom, and the temperature is determined by that of the wire sample.

For small work, which will stand tumbling, case hardening may be accomplished in a special machine, using illuminating gas as the carburizing agent. This special form of construction consists of a cylindrical furnace heated with gas, inside of which rotates a cylindrical retort in which the material to be case hardened is placed. Ordinary illuminating gas is admitted to the retort which furnishes the carburizing material and the results thus produced are the same as those obtained in pack hardening.

Where only a thin case is required, such as in small machine parts, a very quick and effective method is heating the material in a liquid bath of cyanide of potassium. In this method the melted cyanide should be maintained at a little over the upper critical range of the steel, or about 1,550° F. The parts to be treated are usually placed in steel wire baskets and immersed in the bath for a sufficient length of time to give the proper case, but not over 15 to 20 minutes. The material should then be quenched in cold water.

For certain work such as case hardening the heads of bolts, so that they will not mash or scar under the strain of a wrench, the heads are covered with an adhesive mixture of pulverized cyanogen salts and then heated to the proper hardening temperature and quenched.

It has been previously stated that the aim of carburizing is to produce a hard wearing case with the maximum toughness of core. This condition can only be brought about by the proper carburizing temperature and in some cases a subsequent reheating and quenching operation. When the carburizing temperature is not allowed to exceed but slightly that of the upper critical temperature of the steel being treated, and the material is then quenched, the desired results will be obtained. If, however, the temperature is allowed to go much higher than the upper critical range and the material is then quenched, it will produce a very coarse and brittle structure of the case. Under such conditions it becomes necessary to reheat the steel to a point just over the upper critical range and quench. This will produce the desired core with the proper transformation of the case.

A 30-foot specimen of skunk currant (Ribes prostratum). The plant is common in swamps and is very difficult to eradicate

The Blister Rust of the White Pines

A Menace to Our Forests of European Origin

By Samuel J. Record

Foresters, timber owners and others interested in the protection of America's present and future timber supply are coöperating in a strenuous attempt to check the white pine blister rust, a destructive disease of European origin. To this end the Federal Government has appropriated $300,000, half of which is being used in state coöperative work. Maine has appropriated $10,000 for two years; New Hampshire, $28,000 for two years; Vermont, $25,000 for two years (in connection with moth control); Massachusetts $50,000; Rhode Island, $2,500; Connecticut, $15,000 for three years; New York, $25,000; Pennsylvania, $10,000; Wisconsin, $15,000; Minnesota, $15,000; Ontario, $1,500. This makes a total of approximately half a million dollars to repel an invader or to limit its ravages. There is no longer any hope of completely eradicating the disease where firmly established as in New England, but there is good reason to believe that it can be kept out of the great forests of the Far West and certain valuable areas of the lake States. Elsewhere the problem is mostly to minimize the damage by gaining local control.

This disease is caused by a parasitic fungus which attacks the trees of the white pine group. These pines are characterized by having their needle-like leaves in clusters of five, and among them are three of the most valuable timber trees of America, namely, eastern white pine (*Pinus strobus*), western or Idaho white pine (*P. Monticola*), and the California sugar pine (*P. lambertiana*). Although most destructive to seedlings and small trees it attacks and seriously injures, if it does not eventually kill, trees of all ages and sizes. The damage results from the formation of cankers in the bark which sooner or later completely girdle the stem or branch infected and cause the death of the part beyond. The extent of the injury depends upon the size of the tree and the location and number of the infections. A single infection in the lower part of the stem of a young tree is usually fatal within a year or two after the fungus begins to fruit. In old trees infection is confined to the branches and the upper part of the stem, hence such trees succumb slowly. A large tree may live for many years with hundreds of infections in its branches.

The white blister rust is really two diseases in one, being caused by a fungus which during one stage of its life produces a leaf rust of currants and gooseberries. In this respect it closely resembles two well-known diseases, the wheat rust which has one stage on the barberry, and the apple rust which lives part of its life on the red cedar. The destructive stage of the white pine blister rust lives perennially in the bark of the pine. It was known for a long time in Europe in common with other rusts attacking pines. In 1887 it was recognized as a distinct species attacking only five-leaf pines and was named *Peridermium strobi*. The other stage (the currant rust) attacks all species of Ribes (the generic name for currants and gooseberries) both wild and cultivated. It was first noted in Russia in 1856 and named *Cronartium ribicola*. For many years the two stages were supposed to be entirely distinct but comparative observations of their life cycles revealed an apparent relationship. In 1888 Klebahn, a German scientist, inoculated leaves of Ribes with spores of *Peridermium strobi* and produced the characteristic spores of *Cronartium ribicola*, thus proving conclusively that the two supposedly distinct fungi were merely different stages or forms of the same. The fungus is now known only by the name longest in use, *Cronartium ribicola*.

A crew eradicating Ribes in forest. The man at the left guides them with a compass

In order to wage effectual warfare against such a disease one of the first essentials is a knowledge of the life history of the casual organism and of the factors affecting its development and dissemination. The important facts so far available regarding the life history of this fungus are as follows: Beginning with an infection in the pine, there is a period of incubation of indefinite duration (one to several years) during which there is no external sign of the fungus. Eventually the inner layers of the bark begin to thicken and the stem usually becomes decidedly swollen at the place of infection. Patches of this enlarged area become yellowish and from them exude small drops of clear, sweetish fluid which contains great numbers of spores known as pycnospores. They commonly appear very early in the spring but may occur at any time during the growing season. The function of the pycnospores is unknown as they apparently have no part in the dissemination of the disease. They do serve, however, as an excellent diagnostic feature.

The pycnospores are the forerunners of the true fruiting bodies (æcidia), which are produced on the swollen bark from the latter part of April until the middle of June. They first appear as white blisters (hence the name blister rust) varying in size up to as large as the nail on one's little finger. After a few days the outer membrane (peridermium) breaks open and liberates the bright yellow powdery spores (æcidiospores) which fall upon the vegetation beneath or are caught up and carried by the wind to unknown

Crew inspecting a white pine plantation for blister rust

Scouts inspecting currant bushes for white pine blister rust

distances. Spores continue to be produced for about two weeks and immense quantities are dispersed. At Kittery Point, Maine, where the pine infection is very severe, the agitation of the top of a large tree would liberate a cloud of spores which could be traced for considerable distance in the air.

The various species of Ribes, either cultivated or wild, are so generously and ubiquitously distributed throughout the range of the white pines that a better combination of hosts for the effective distribution of a fungus could hardly be conceived. Currants and

Magnified portion of the underside of a currant leaf showing pustules of uredospores

gooseberries are among the earliest plants to put forth their leaves and some of the spores from the pines are, under normal conditions, reasonable sure to fall upon them. If the conditions of moisture and warmth are favorable the æcidiospores germinate very quickly (usually within a few hours) and those on the leaves of Ribes grow down into the soft tissues and in about two weeks have developed sufficiently to

A currant bush uprooted at the edge of a meadow. It usually requires two men to extract a well set bush.

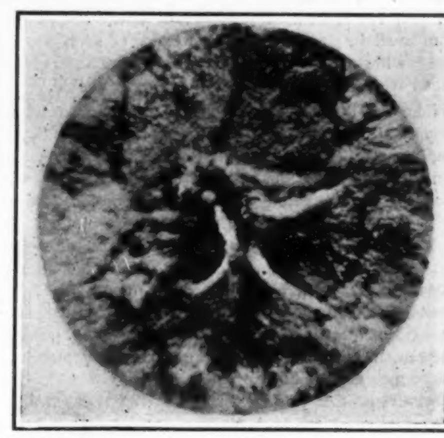
White pine blister rust on a young tree that originated in Europe. Natural size

fruit. Each spore produces on the under side of the leaf a tiny pustule, not larger than a pin-head, of orange-yellow spores known as uredospores. Sometimes these are few and scattering; again the whole underside of the leaf may be covered with the powdery masses, depending upon the number of infections. The damage to Ribes varies accordingly and ordinarily is not serious enough to kill the plant. Such injury can be largely controlled by thoroughly spraying both sides of the leaves with Bordeaux mixture, but such means are not sufficient to guarantee the destruction of every spore, an essential to the prevention of further spread of the disease.

These uredospores very closely resemble the æcidiospores and like them cannot infect pine. They can only infect currant and gooseberry leaves and rarely

Underside of a black currant leaf showing pustules of uredospores. The telial stage is also present in two places

the young shoots also. Since a new crop of spores is produced about every two weeks from the first of June until leaf fall it is evident that this repeating stage, as it is called, is the most important in the spread of the fungus over large areas. A few scattering infections from pines may in this way be multiplied into very plentiful and heavy infection of all Ribes in the vicinity. While the spores are mainly disseminated by the wind they may also be carried by other agencies such as insects and birds. No limit of range has been determined but under ordinary con-



Magnified portion of underside of currant leaf showing filament upon which the teliospores are borne

ditions is considered to be somewhat less than a mile.

From about the middle of July until the leaves have fallen in the autumn another form of fruiting body and of spores is produced upon the leaves of Ribes, usually but not always upon the same spots which earlier

A scout putting infected leaves in a "pickle roll" to preserve them for later examination and study

bore the uredospores. This new form appears as groups of few to many short, stout, curved hairs becoming brown in color and arranged in little circles. Upon these filaments are produced what are known as teliospores or teleutospores. It is through their agency that the fungus gets back to pine, but even here an indirect method is followed. First the teliospore germinates, sending out a simple germ tube. This tube in turn produces a number of thin-walled bodies known as sporidia. Borne by the wind to the pine these delicate sporidia germinate and grow into the bark either directly or through the leaves (the exact manner having not yet been determined). This completes the complicated life cycle of the fungus. The sporidia cannot infect any plant other than a five-leaf pine and this infection must take place in the late summer or autumn. Owing to the long time elapsing between infection and the first appearance of the disease (one to several years) it is not known how far the spores may be carried. Such evidence as is available indicates that the distance usually is not great, that is, less than 60 feet.

The blister rust of white pines came to America in shipments of young nursery stock, mostly from a single nursery in Germany. For a number of years it was customary for nurserymen here to import young seedlings and to grow them to larger sizes, either because such stock was not available here or could be purchased more cheaply abroad. Many millions of trees were thus introduced and widely distributed over the northeastern quarter of the United States and parts of Canada for forestation and ornamental purposes. Even the most careful methods of inspection and fumigation at the port of entry are of little or no avail in preventing the entrance of such diseased trees owing to the long period of incubation of the fungus when no external characters are visible.

When the disease was first detected here effort was made to stamp it out and for a time there was hope of complete eradication. Recent outbreaks, however, have been so numerous and general that it is now recognized as impracticable to attempt complete eradication. Throughout New England and eastern New York the infection on pines and Ribes is so general that all of the recent white pine plantations and the native young growth is seriously menaced. Except possibly in Rhode Island, state-wide control seems out of the question, but methods are being perfected whereby it is believed that the best white pine areas can be protected at justifiable expense.

Outside of this heavily infected area there are scattered pine and Ribes infections in central and western New York, New Jersey, Pennsylvania, Ohio and Wisconsin. The only appearance of the disease so far reported from Michigan was in a nursery near Detroit and it is hoped that all diseased specimens have been destroyed. In Minnesota it has been found scattered over a strip some 65 miles long and 10 miles wide between St. Paul and Duluth. The disease is not known to occur west of the Mississippi River, although in Colorado a rust on Ribes has been found which may prove to be *Cronartium ribicola*.

The fight now being vigorously prosecuted to gain control over this disease presents various phases. The Federal Horticultural Board of the U. S. Department of Agriculture has declared a quarantine against the shipment of white pine nursery stock west of and including Minnesota, Iowa, Missouri, Arkansas and Louisiana. The importation of white pines and gooseberry and currant plants from Europe and Asia is also prohibited. The shipment of five-leaf pines and of black currant bushes from New England and New York to states little or not at all infected is no longer permitted. Many of the states have established quarantines against the introduction of white pine and Ribes from other states and in some instances have quarantined certain areas within the state boundaries. It was formerly believed that *Cronarium ribicola* did not survive the winter on Ribes, and that dormant plants of the latter could be used without danger of spreading the disease. The recent discovery that the uredospores are sometimes borne on the young shoots instead of being entirely confined to the leaves indicates that such is not always the case.

In regions of scattered or limited infection, scouting is being done to locate the rust with a view to eradicating it from such areas by destroying the infected pines and Ribes, or by attempting to prevent further spread by means of a Ribes-free protective zone or belt. New York, for example, is trying to check the westward and southern spread of the fungus by completely removing all currant and gooseberry plants from a strip two miles wide. Advantage is taken of the open farm land in doing this so as to make the eradication of Ribes easier and more nearly complete. The further planting of such bushes in a barred zone is prohibited.

The recent ineffectual attempt to control the chestnut blight, another importation, has no bearing upon the possibility of controlling the blister rust. The one spreads directly from tree to tree or from one part of a tree to another; the other requires two distinct hosts for its development and spread thus making it possible of control in any locality where white pine and Ribes can be sufficiently separated. Since every infection on a pine is localized and cannot spread directly to other trees or to other portions of the same tree it follows that control measures may be feasible even where the infection is severe. This applies particularly to the older trees where the damage is mostly to the younger portions of the branches. In generally infected areas such as New England, however, the question is not what is possible with unlimited funds and labor, but rather how much trouble and expense the protection of the pine will justify. The essential thing now is to demonstrate through experimental eradication areas that local control is feasible and then through cooperation with the timber owners to apply these measures to the protection of such forests as will warrant the expense.

Such demonstration areas are now being established in the various New England states and most of the field work of the immediate future will be confined to them. The general plan is to choose an area of white pine to protect and then to remove all Ribes from this tract and for at least a mile beyond it. The wild plants give the most trouble and crews of men work back and forth systematically through the woods pulling up or digging out every currant or gooseberry bush they can find. Where the ground cover is dense and luxuriant, as in swamps and lowlands, the eradication of the plants is very tedious and even the most efficient crews cannot expect to get all of them at one operation. Moreover, portions left in the ground may sprout later. Consequently it is necessary to go over the same tract each season for three or four successive years. The work after the first season can be greatly expedited by taking advantage of the fact that currants and gooseberries come into leaf about two weeks in advance of the other vegetation and the few bushes remaining from the preceding year's work are at this time readily detected and removed.

The indiscriminate destruction of cultivated plants of value is not advisable except in areas where a general clean-up of all Ribes is seriously attempted. Pulling out fruiting currants and gooseberries and leaving the wild ones in the woods untouched will accomplish no good and should be avoided. Incomplete eradication of the wild plants will not serve the purpose of arresting the disease, and work along this line should not be undertaken except with a view to continuing it until all of the Ribes plants in the eradication area are removed and the introduction of others prevented.

That the blister rust of white pine was ever allowed to gain a foothold in this country is an extremely unfortunate occurrence which could readily have been prevented had the warnings of European foresters been heeded in time. It is now permanently established over large areas and must be seriously considered in all future forestry operations involving white pine. The big problem now is to keep it out of the vast forests as yet unaffected. Elsewhere it means that white pine must be put in the class with cultivated plants and that growing it successfully in future involves the sacrifice of all currants and gooseberries in that locality. In regions where the necessary protection is not feasible our native red or Norway pine (*Pinus resinosa*) should prove an acceptable substitute for the eastern white pine. This tree grows rapidly, appears immune to all serious insect and fungous pests, and for most of the purposes to which second-growth material is put it serves equally as well as the white pine.

Developing Crystallized Mineral Specimens

By Alfred C. Hawkins

AMONG the most attractive and highly prized specimens in any collection are the crystallized ones. The most valuable crystal is usually the one which is attached to the matrix in a manner which by suitable contrast of color and form serves to show forth its beauty and symmetry to the greatest possible degree. We naturally prefer also that the crystal should never have been removed from this matrix, nor artificially attached to either its natural matrix, or, (as sometimes occurs), to a kind of rock or mineral aggregate where it never belonged.

While it is true that an occasional specimen in which the crystals are imbedded in a solid matrix will break at the time of original collecting in such a way as to expose the crystals to the best advantage, yet probably the best of such matrix specimens seen in our collections have been "developed" to some extent. Crystallized material of this type is often put upon the market in the crude form in which it was obtained from the quarry. In such cases the wise purchaser will have ample opportunity to increase the beauty of appearance, as well as the value, of his "finds."

There are two principal ways of removing the superfluous matrix which surrounds and covers the crystals; the first is by solution, the second by cutting it out with tools.

Dilute hydrochloric or nitric acid is used in the solution process. Limestone matrix is easily removed in this way; it goes into solution quickly and the only requirement for continued action is the addition of fresh acid when necessary. Other less common matrix materials may be treated in a similar way, but react differently; as, for instance, the natrolite surrounding the benitoite and neptunite crystals from California, which, during treatment with acid, forms a thick, insoluble jelly. This colloidal substance collects in a layer which protects the surface of the mineral below; it must be scraped off at intervals before fresh acid is applied. Above all things else it is necessary when treating specimens with acid, to make sure that the crystals which are to be brought into relief are not themselves attacked by the solvent, which would result in the destruction of the luster of crystal faces or of the solid angles of the crystals. Many Franklin Furnace specimens have been permanently ruined in this way. Careful reference to a standard textbook on mineralogy will determine this important point in advance. After treatment with acid, specimens should be soaked for some time in water, preferably warm, providing, of course, that the crystals are insoluble in water, or in a weak ammonia solution, to remove and neutralize all traces of acid which may be left. Acid remaining gives a yellow color, acidic odor and corrosive action on labels and trays.

For removal of matrix which is not attacked by acids, small steel chisels or pointed instruments are used. The writer has used straight sail-needles, whose points were renewed at intervals on a grind-stone. In the use of pointed instruments, extreme care and patience are necessary, as a single slip may damage a valuable crystal beyond repair. The chisel should be held firmly and the hand braced against the specimen or its support. Perhaps the greatest danger of injury to the crystal occurs when the surrounding material suddenly breaks away under the blows of the hammer, exposing the crystal face just beneath. In working away the matrix close to a crystal, the direction of the blows should always be away from it. This avoids bruising of crystal faces. The hammer itself should be light in weight, with a flat face, preferably square. The handle should be of wood, long and flexible. The blows should usually be short, sharp taps, causing the least possible jar to the specimen. It will be found that when excessive jar occurs, the most severe breakage is likely to be on the side of the specimen farthest from the point where the blow was delivered, as the stresses are transmitted through the specimen to that point. The specimen can be supported in some way to deaden the jar—in a box of sand, or upon a cloth bag filled with sand. The matrix should be removed slowly, grain by grain, if granular. Thus the quartz of pegmatite veins is easily removed when it is granular, especially when somewhat shattered by quarrying operations. Other kinds of matrix, like the sericite schist in the cyanite-staurolite specimens of Switzerland will separate in thin flakes. Care should always be taken to remove as little as possible at a time. Very hard materials, like massive or crystalline natrolite, can sometimes be first attacked with acid and then removed with the chisel.

It must be remembered that the average crystal in a matrix like a limestone or a pegmatite vein has no natural cement attaching it to its matrix; it simply lies in a smooth cavity whose walls correspond to its crystal faces. Hence enough matrix should be left surrounding the crystal to hold it firmly in its place.

Crystals imbedded in solid vein material (especially in veins or dikes in metamorphic rocks), will occasionally be found to be naturally shattered by earth movements into many small pieces, some of which fall away when the crystal is exposed. This is true, for instance, of some garnets, tourmalines, and apatites from New York City. In other cases, portions of brittle crystals may be chipped off with the matrix, to which portions, especially the solid angles, sometimes adhere. In case breakage of crystals occurs, it is frequently possible to repair them, filling any small cracks with a paste made of small fragments of crystals of the same kind and color, mixed with glue.—*The American Mineralogist.*

The Cause of the So-Called Pole-Effect in the Electric Arc

By T. Royds

Differences of vapor-density were first suggested in *Kodaikanal Observatory Bulletin*, No. 38, as the cause of the displacements of certain lines in different parts and conditions of the electric arc, and of the abnormal sun-minus-arc displacements of the same lines. Since, however, direct experimental proof is wanting, and has been said to give negative results, it seems desirable to discuss the evidence and experiments at the point at which work here on the subject has to be abandoned.

The cause of the displacements in the electric arc has also been treated by St. John and Babcock,[1] Gale and Whitney,[2] and Whitney,[3] none of whom discusses the evidence and conclusion in *Kodaikanal Observatory Bulletin*, Nos. 38 and 40.[4]

In the last two papers on experiments with a calcium arc, the pole displacement is ascribed to the greater amplitude of vibration of the electrons, and is said to depend on the intensity-gradient along the arc. The latter phrase is unfortunate, as, so far as I understand them, the authors do not mean the rate of change of intensity, but intensity-differences.

It must be obvious to every experimenter that the intensity of lines is great in those regions of the arc where displacement occurs; but, as it is equally true of lines which do not undergo displacement and of those which are displaced to the red and to the violet, one fails to see how the displacement can be said to depend on the intensity-differences. One might with equal or more truth say that the displacement depends on the width of the spectral lines, or on their diffuseness, but for reasons which have already been elaborated,[5] I believe that the displacement depends on the unsymmetrical character of the spectral lines. I have not met with a single case where lines whose character was known were not displaced, either not at all, to the red, or to the violet, according as they were symmetrical, unsymmetrically widened toward the red, or unsymmetrically widened toward the violet, *except under those conditions, e.g., in reversals, where the vapor-density has been kept low.* Of course these phenomena—unsymmetrical character, intensity, etc.—are not the *cause* of the displacement, but are attendant effects due probably to the same cause.

Increased amplitude of vibration of the electrons is suggested by Gale and Whitney[6] as the cause of the displacement in the electric arc, but it is easy to see that this cannot be. The most effective and probably the only certain way known to me of increasing the amplitude of vibration of the electrons in the atom is to raise the temperature, but the displacements in the arc are not an effect of temperature, for many reasons, among which the three following seem sufficient.

1. Little is known of the variation of temperature along the arc, but it is certain that the positive pole is much hotter than the negative, whereas under normal conditions the displacement is greatest near the latter. The enhanced lines, which are high-temperature lines, appear stronger at the positive pole than at the negative,[7] also indicating that the temperature is higher there than at the negative pole.

2. The experiments described in *Kodaikanal Observatory Bulletin*, No. 40, and here, show that the displacement at the negative pole can be varied to any desired extent without reason for believing that the temperature of the arc is altered in any appreciable degree.

3. In the sun's reversing layer, where the temperature exceeds that attainable in the arc, the displacement of lines unsymmetrical in the arc is in the direction *opposite* to that of the displacement at the poles of the arc.

Although the evidence given in *Kodaikanal Observatory Bulletin*, Nos. 38 and 40, is strongly in favor of density as the cause of the displacements, there are many difficulties in the way of direct experimental proof, due primarily to the difficulty of controlling the vapor-density in a source of light. Experiments with different quantities of material, such as those giving Gale and Whitney's Tables III and IV. fail; or at any rate are inconclusive, because there is no reason to believe that the atoms have been separated a greater distance with the smaller amount of material. If the atoms are vaporized in clusters, they may not be removed from each other's influence any more than when a larger amount has been used. Exposure-times are not a sufficient test of vapor-density, but only an indication of the total amount of material consumed.

On account of this difficulty it was thought better to use alloys as electrodes. Presumably the molecules in an alloy are so intimately mixed with another metal that each would be surrounded by molecules of another kind, and would be removed from the influence of those of the same kind. Even so, the experiments gave negative results. The best alloys available were the coins of the Indian coinage, the silver coins containing 10 per cent of copper, and the nickel coins containing 20 per cent. As the silver coins, and the money they represent, melt away rapidly and do not give a steady arc, the experiments were conducted mostly with nickel coins (value one anna). With a nickel coin as one electrode, and the other another coin, iron, or carbon, the wave-lengths and displacements of the three copper lines —— 4480, 4509, and 4531 were compared with those in the arc between copper electrodes with the same length of arc and current-strength. The maximum displacement of the first and last was about +0.05 A and of the second about +0.025 A. The wave-length at the center of the alloy arc was identical with that at the center of the pure copper arc, but it was found that the wave-length at the negative pole could be varied at will by varying the material of the negative electrode. With carbon as negative electrode and the nickel coin or copper as the positive, the displacement of the copper lines at the negative electrode could be made very small, especially with those conditions when the green luminosity surrounding the positive electrode did not reach up to the negative which showed the characteristic blue of the carbon arc. When the nickel coin is negative, and the positive pole a coin, iron, or carbon, there is on the other hand not the slightest difficulty in obtaining displacements at the negative quite as large as those at the negative pole of the arc between two copper electrodes.

The results with the alloy were therefore, in the main, disappointing, especially the fact that the wave-length at the center of the alloy arc was identical with that at the center of the pure metal arc. There is, however, one case, the sodium pair —— 5682, 5688, where it is possible to obtain a displacement in the same direction as that in the sun and opposite to that usual at the negative pole. The data are given in *Kodaikanal Observatory Bulletin*, No. 40. The solar displacement of these lines, comparing the center of the sun's disk with the center of a very long arc, is —0.14 A (i.e., to the violet), the displacement of the unreversed line at the negative pole is +0.36 A, while the displacement of the *reversal* which occurs at the negative pole is —0.019 A. The sodium pair is very sensitive to displacement, and is only a case more extreme than many others, found in the bulletin referred to, for which the displacement at the negative pole is much smaller if the line undergoes reversal there than if the line remains unreversed. A new example of this has turned up in the first subordinate triplet of calcium near — 4450. If the lines are reversed at the negative pole, the displacement is quite small or zero[8] and the lines appear almost, if not quite, symmetrical.[9] If, however, the lines are obtained unreversed at the negative pole, the displacement amounts to about —0.012 A and the unsymmetrical widening toward the violet is evident.

I have not met with cases such as that recorded by Whitney, where the displacement of the reversal was identical with that of the unreversed lines (it is not so for these lines on my photographs), but there is nothing impossible in it on the density hypothesis.

The only way in which the results with the alloy and pure metal can be reconciled with the density hypothesis is to suppose that the density-differences effective in producing the displacements are of a much higher order than those obtained using the alloy containing 20 per cent of the metal investigated. It would seem that the atoms influence each other only soon after they are torn off from the electrode, as if they occur there in compact clusters which are soon dissipated so that when they reach the center of the arc the atoms are removed out of each other's influence. In the sun the density is supposed to be so small that a farther separation and displacement takes place. If the density-effect is due to the mutual electrical fields of the atoms, it is conceivable that fields of atoms of a different kind would also have an influence, thus explaining the considerable displacement at the poles of the alloy arc compared with the pure metal arc.

The considerations of the last paragraph would also explain the negative results of St. John and Babcock, but it cannot be conceded without further information that increasing the quantity vaporized increases the vapor-density in the furnace in the same ratio. One would have thought that the greater the quantity of material vaporized the greater would be the rate of its removal by condensation on the cooler parts of the tube.

The really interesting result of Gale and Whitney's and of Whitney's experiments is that they have, apparently, succeeded in obtaining arc conditions which bring the normal displacement at the negative pole of the arc down to zero, and even, for the more sensitive lines in the direction opposite to the usual one, i.e., in the same direction as the sun-minus-arc displacement.

I agree with Duffield's remarks on the influence of density- and temperature-gradients in light-sources on the displacement of spectral lines,[9] but I should like to make clear that the gradients cannot have any influence unless density and temperature are themselves causes of displacement.

Although direct experimental proof has not been obtained, I cannot find any hypothesis other than density to explain the displacement of certain spectral lines in different parts and conditions of the arc and the abnormal sun-minus-arc displacement of the same lines which have been discussed in *Kodaikanal Observatory Bulletin*, Nos. 38 and 40. Whether some additional conditions are necessary, or whether the density-differences effective in displacing lines are larger than those hitherto attempted, are points for further experiment. It is hoped that a source of light may be constructed where the vapor-density can be varied over a large range when it is possible to resume these experiments.

Astrophysical Journal.

[1] *Astrophysical Journal*, 42, 231, 1915.

[2] *Ibid.*, 43, 161, 1916.

[3] *Ibid.*, 44, 65, 1916.

[4] Both these bulletins appeared in 1914.

[5] Royds, *Kodaik Observatory Bulletin*, Nos. 38, 40.

[6] *Loc. cit.*

[7] A. Fowler, *Monthly Notices*, 67, 154, 1907.

[8] Royds, *Kodaikanal Observatory Bulletin*, No. 40.

[9] Royds, *Astrophysical Journal*, 41, 154, 1915, and *Kodaikanal Observatory Bulletin*, No. 43.

Salt-Licks and Alkali Springs for Elk

In some states it is unlawful to make a salt-lick. Hunters sometimes make a lick to lure the deer in to be shot, and in the west a successful way to hunt for meat is to watch a lick during the evening or early morning. Some very timid animals have been lured with salt to within a few feet of the camera, to get their pictures.

In the West, all herbivorous animals—elk deer, moose, antelope, mountain sheep, horses and cattle—seem to require either salt or alkali water. It is not the salty taste that is sought, for in Jackson's Hole neither the earth nor the water that oozes out has a salty or brackish taste. The water is a cathartic, both to man and beast. Natural salt-licks are not often found in a granite or volcanic formation, and the wild animals that range there must, in most cases, travel for miles to reach the nearest lick. Great trails are worn out, some of which have been in use for ages. Loads and loads of the earth are eaten by them for the salt or alkali that it contains, and that is necessary for their existence. Without it they become sluggish, their hair has a dead look, their eye loses its fire, and their spirit and energy are diminished. Sometimes their actions really denote debility.

The larger portion of the basin of Jackson's Hole is of sedimentary origin. It contains many veins of coal, sand-stone, slate, shale, and limestone. It also contains many natural alkali springs that are used very extensively by the elk. I think that this, as much as any other one thing, accounts for their being there. The few elk that range outside the limits of these springs will leave their range and travel for miles to the nearest lick, and on drawing near it will come in on the run, and begin immediately to sip the water or eat the earth.

Elk will hang around a spring for several days before returning to their range. To draw an irregular circle to include all the alkali springs in the Jackson's Hole country, would include nearly all the elk, and though other portions of the county in every other way are adapted to the needs of the elk, they will not stay elsewhere because there are no alkali-licks. In other words, where the licks are, there the elk will be found during the summer.

Years ago the elk went to a lower country to winter, where there were other licks, also salt-grass and salt-sage. Now their winter range is confined to the lower portion of this valley, where there are no licks they can get at, and where there is neither salt-grass nor salt-sage. Under such conditions, we salt our horses and cattle at least every two weeks, to keep them healthy and in a thriving condition.

Is it reasonable, therefore, to expect that the elk can go for three or four months through this period without salt, and remain in a healthy condition?—S. N. Leek, in the *N. Y. Zoological Society Bulletin*.

The Making of a 6-inch Reflecting Telescope—I.

Instructions for the Amateur Instrument Builder

By C. J. Larson, M.D.

I.—General Considerations

This article is intended for the amateur astronomer; to interest him and to help him in building for himself a telescope of a type that fortunately is well adapted for construction by the average amateur, and of materials obtainable in most any community. The author being an amateur himself his qualifications for writing on the subject may be questioned. My qualification—if I may claim any—is that I am an *amateur*, and this fact should be heartening to the reader.

Two years ago I should have thought it impossible for my self to construct a reflecting telescope. My interest was awakened by two little articles found in back files of the Scientific American. I tried to make a concave mirror—and succeeded. But I could find no article completely describing the making of all parts of such a telescope, including mounting and all accessories. Ritchey's classic article describes the grinding and testing of five-foot and two-foot reflectors. Draper's excellent paper deals with 15-inch instruments. There are other writers that treat of some particular part or feature of such an apparatus. After reading the available literature I found there were still some points upon which I had no information, and inquiries and experimentation had to be resorted to. Then I constructed the telescope, working out the mechanical detail as best I could and of the materials I could obtain. I was quite satisfied with the result, and it occurred to me that all efforts should be made to acquaint the amateur astronomer with the fact that *it is* possible for him to make his own reflector.

The grinding and polishing of the mirror and the silvering operations will be new experiences to most persons; and the ones they most fear. Many will doubt that such work can be done by amateurs. I will say that it is rather remarkable that such an instrument of precision as a so-called "silver on glass" telescope mirror can be produced by the average amateur astronomer, and of such commonplace materials as a piece of plate glass and emery powder. But it can be done, if directions are carefully followed. Successful accomplishment in these two features of the work requires that directions be followed to the letter. A little time and patience will be demanded in the process of grinding and polishing, but when the worker sees that the glass is actually coming to a concave figure he will feel an elation that can hardly be expressed. But aside from the figuring and silvering of the mirror, the work presents no special nor unusual mechanical problems, and any one possessing a little mechanical ingenuity may vary the mechanical detail according to the material at hand and other facilities, as long as the principles are adhered to. My object in describing the construction of all parts as I have done, is to point out in a way the easiest and best manner in which the desired results can be secured with the materials and means that the average amateur will be liable to have. For instance, he may try several ways of mounting the flat (I did), may expend considerable time and effort that will prove to be lost time and effort. But if he can go at it directly as here described, but little labor will be expended, and the materials needed are only a cylindrical piece of wood (or a square one if the flat is rectangular in shape), a piece of tin, a long light bolt or a wooden rod, six light wires with a small bolt attached to one end of each, and a surprisingly serviceable mounting for the flat is the result, one that provides for its accurate adjustment in all ways.

The high cost of refracting telescopes has always been a great discouragement to the amateur astronomer. He reads of the great telescopes with object glasses of 20 and 30 and even 40-inch diameter; and glasses of three and four-inch size are often referred to as small, and even as "tiny," and when he learns that an instrument of not more than four inches costs hundreds of dollars fully mounted, he is inclined to think that astronomy, like some other amusements, is only for the rich. The reflecting telescope is his salvation. A good reflecting telescope may be bought completed for a price of from one-quarter to one-eighth of that of a refractor of similar size. And if he fears the figuring and silvering of the speculum, he may buy that part and thus confine his efforts to the construction of the mounting for the optical parts. And in sizes not greater than six or eight inches the mirror can be easily and at small cost sent to the maker for resilvering when tarnish occurs.

A little advice to the beginner in the study of the heavens may not be out of place here. Some think the first requisite to astronomical study is a telescope. They may wander into a shop to buy a telescope and a book on astronomy. If they cannot get a satisfactory deal on the telescope they then and there terminate their astronomical careers, before they began them one might say. You can study the heavens for years with the eye alone without exhausting the possibilities of naked eye work. One of the greatest astronomers of all time, Tycho Brahe, never looked through a telescope. And too, few realize, or even dream of, what may be done with a very small glass, two inches or even an inch and a half. So here I would advise those just beginning to get a spyglass, and a medium priced one. Familiarize themselves with the features of the telescope, its use, both with terrestrial objects—ships in the distance, spires and hilltops afar—as well as with heavenly bodies. Then make a reflector of 6 or 5 or 4-inch size, and then your little refractor will be extremely useful for a "finder" for your reflector, or for that matter for any larger telescope of any type. The manner of mounting and using a finder will be detailed further on.

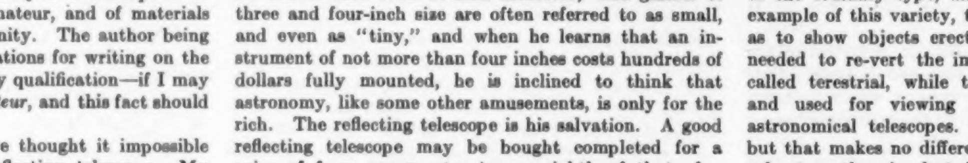


Fig. 1—Refracting telescope

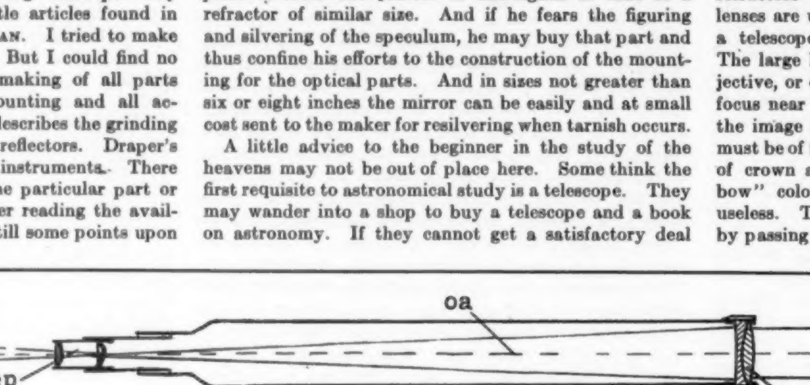


Fig. 2—Newtonian reflecting telescope

Fig. 3—Cassegrainian type

Fig. 4—Herschell's type

oa—Optical axis. og—Object glass. ep—Eyepiece. sp—Speculum. df—Diagonal flat. cm—Convex mirror

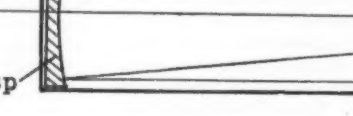


Fig. 5—Negative eyepiece
el—Eye lens. fl—Field lens

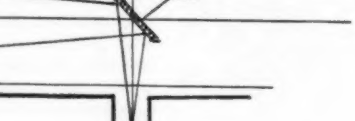


Fig. 6—Positive eyepiece
el—Eye lens. fl—Field lens

II.—Definition of Terms Used and Discussion of Optical Principles Used

It might be well at this point to define and explain some of the words and terms used in telescopic literature; and also to discuss some of the optical principles involved.

Refractor, or refracting telescope, is the term applied to the ordinary type, and the common spyglass is an example of this variety, though the eyeglass is made so as to show objects erect, two additional lenses being needed to re-vert the image. Glasses used thus are called terrestrial, while those with a simple eyepiece and used for viewing heavenly bodies are termed astronomical telescopes. Objects are shown inverted, but that makes no difference in this class of work. In refractors the simplest form is that where only two lenses are used, and by employing even spectacle lenses a telescope can be made that might surprise some. The large lens at the end of the tube is called the objective, or object glass, and brings the rays of light to a focus near the eyepiece where the latter then magnifies the image almost as a microscope does. The objective must be of fine optical glass, and made of two lenses—one of crown and one of flint glass—otherwise the "rainbow" colors become so marked as to make it almost useless. The rays of light are bent, or "refracted," by passing through the glass—hence the name, and also the need of "optical" glass, and too, the high price.

Reflector, or reflecting telescope, is used to designate the type where the rays of light are reflected back from a silvered concave surface, but from there on the light rays after being brought to a focus are subjected to the action of the eyepiece as in the other type. The hollowed out mirror is commonly called the speculum, though the terms mirror and reflector are also used interchangeably with speculum. Sometimes the mirror is even referred to as the "objective," though rarely so nowadays. The silvered plane, or flat, set at an angle of 45 degrees to deflect the rays to the eyepiece tube, is often called the "diagonal." So it is seen that in the reflector the light does not pass through the glass but is reflected from a silvered surface, and thus the glass need not be the high grade optical glass required in the refractor. The term "glass" is often applied to a complete telescope of either kind, as for instance when one says a certain object is visible in a three-inch glass. Figures 1 and 2 indicate diagrammatically the relation of the optical parts and the paths of the light rays in the two types of telescopes described above.

An alloy of copper and tin, commonly called speculum metal, was used exclusively for specula until about 60 years ago; but about that time Liebig discovered the chemical deposition of metallic silver on glass surfaces, and a new era in reflectors opened. "Silver on glass," or its abbreviation "s. o. g." denotes glass specula in contradistinction to metallic ones, but as glass mirrors are now used altogether this designation is being dropped.

Optical glass is made of carefully selected materials, and by stirring the molten glass in its pot with a rod of fireclay until it gets so stiff that further stirring is impossible it thus becomes of a uniform consistency, instead of having veins of glass of different density as otherwise would be the case. The finest, clearest plate glass, if made into a lens and used with an eyepiece will show a number of striae and these so distort the image as to render it useless. But plate glass if sufficiently thick does well for specula, especially for the smaller sizes. In the larger sizes, from a foot up, the quality of the glass must be almost of optical grade for the reason that the striae of uneven density do not contract and expand uniformly under changes of temperature,

and the distortion thus produced as well as that caused by flexures due to different positions will not produce correct images. Notice the distortion in the images seen in a common cheap mirror, the kind that is not plate glass even, and also observe the distortion of images that occurs when looking through a window of common glass. Imagine these defects magnified from 50 to 100 times. But remember that in a reflector these defects are objectionable only because the figure of the surface is affected by the uneven expansion or contraction of temperature changes, or the uneven effects of gravity upon the different densities of these veins.

Light is not a substance being shot through space, but it is a vibration, or series of waves, in that imponderable thing called aether, which seems to fill all space.

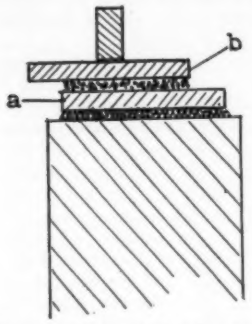


Fig. 7.—a, Glass tool cemented to post; b, speculum with handle cemented to it

Its speed is such that it could travel around the earth seven times in one second. It goes in straight lines unless it encounters something of differing "optical" density. An object looks large or small as the visual angle varies. You look at a building near by and the angle made by a line from the top of the building to your eye and a line from the bottom to your eye is a large angle. At a distance this same building looks smaller because these lines are more nearly parallel and the visual angle at the eye is smaller. If you use a telescope to view this object, the rays of the light are bent, or refracted towards the central line running through your eye and the center of the telescope. And so when the rays from the extremities of the object enter the eye, they make a large angle and thus the object viewed appears larger and consequently nearer. The line through the center of eyepiece and objective is known as the "optical axis."

The amateur's conception of the relationship of great size and high magnification is substantially correct. The size of a telescope is usually expressed in "aperture" of object glass or speculum. "Clear aperture" is sometimes used, as it is the area of glass actually exposed that determines its effective size. The cell is the ring or collar in which the objective or speculum is mounted.

"Focus," or focal length, is the distance from the lens or mirror to the point where the rays come together. A burning glass must be held at a certain distance to get the needed concentration of rays from the sun, and that distance is its focal length. Eyepieces are usually styled as being of an "equivalent focus" of so many inches, or of such a fraction of an inch, and this designation is used because eyepieces are composed of two lenses, and the "equivalent" focus is that of the combination; so if an eyepiece is rated "e. f. 1½-inch" it has the same refracting power as a single lens of a 1½ inch focus. A single lens can be used as an eyepiece, but definition is good only near the center, and rainbow colors develop. In the two lens combinations used the curves of the surfaces and the distances at which the two lenses are placed are such as to practically do away with the color, and the definition is good clear to the edge of the field. The two eyepieces most used are the "negative," or Huyghenian, and the "positive," or Ramdsen. In both forms the lenses used are flat on one side and convex on the other. In negative oculars both lenses have the flat side towards the eye, and positive eyepieces have the lens farthest from the eye in a reversed position. If cross wires are used they must be placed between the lenses of a negative eyepiece and outside of and in front of the combination in a positive ocular. The power of an eyepiece varies with its equivalent focus, a two inch e. f. giving one-quarter as great magnification as one of one-half in e. f.

The magnification of any telescope depends upon two factors—the focal lengths of the objective or speculum, and of the eyepiece. The eyepieces are the same in both refractors and reflectors. If the objective has a focus of 50 inches and a ½-inch eyepiece is used, a magnification of 100 diameters is obtained, because magnification equals focus of objective divided by equivalent focus of eyepiece. So to obtain different magnifications with a certain telescope it is evidently better to use different strength eyepieces than to substitute objectives of differing focus. Oculars should be marked in inches e. f., and not in diameters of magnification, because a one-inch eyepiece used with an objective of 50-inch focus, while giving 50 diameters magnification with that combination, will give 100 diameters with a 100-inch focal length object glass, and only 25 diameters with one of 25-inch focus.

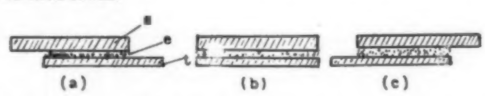


Fig. 8.—Showing relative positions of speculum and tool in different parts of stroke. s, speculum; t, tool; e, emery

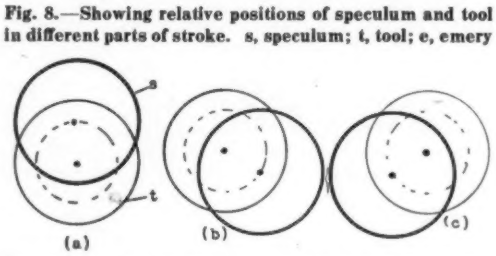


Fig. 9.—Showing positions of speculum and tool in circular stroke. s, speculum; t, tool

Telescopes are always rated according to aperture of objective or mirror, so we say a 10-inch, or a two-inch. Then one learns that magnification, and what is the same, the apparent size of the object in the telescope, depends upon the proportion of the focal lengths of objective and eyepiece. Why say four-inch glass? Why not say 100 power, or magnifying power of 100; and spyglasses are usually so designated. And why not increase magnification indefinitely by making any size object glass of very long focus, or using very short focus eyepieces? The reason is: there are just so many light rays falling on a certain area of object glass or mirror, the amount of light thus gathered being in proportion to the area of glass exposed. This amount of light has, one may say, to be spread out over so and so much magnification, and beyond a certain point the illumination thus becomes so reduced as to be insufficient to affect the cells of the retina of the eye. It is like spreading butter on bread—the more you spread it out over the bread the thinner the butter will be. So with objectives of "astronomical" grade, which must be the best, the light gathering power, or "light grasp," is in proportion to the area, and this of course varies as the square of the diameter. And so a certain size of objective will stand a certain amount of magnification. The larger the glass the greater the magnification that may be used, or the brighter the image with a given magnification. As a rule about 75 diameters magnification per inch of object glass is about the limit. The atmosphere affects the "seeing" to a very great extent; though there may be no clouds nor haze nor mists, different layers of air may have very different temperatures and consequently different densities, and with air currents hither and thither the "seeing" may be so poor as to make any degree of definition impossible.

III. REFLECTORS AND REFRACTORS COMPARED

The relative merits and demerits of the two types of telescopes have been much discussed and the stereotyped lists of advantages and disadvantages of each are familiar to anyone having turned the pages of the average text book of astronomy. Let it not be inferred that because I am writing on the construction of home-made reflectors that I consider that type the superior. By no means.

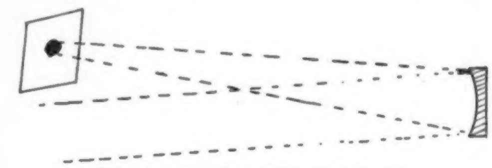


Fig. 10.—Rough test for focal length

Were it possible for the amateur to make a 6-inch refractor, or even one of 4 inches, as easily and cheaply as a 6-inch reflector, I should detail its construction with greater enthusiasm. But there are those who really are prejudiced against the reflector, and some even refer to it with actual contempt; but I suspicion that those expressing the latter sentiment do so because they happen to have the "price" of a refractor and consider the reflector a "cheap" instrument.

It is generally admitted that as an all-around working instrument the refractor is to be preferred. It usually defines better, and is more easily handled and kept in order. The reflector is superior for photography and spectroscopic work, and as the photographic plate has almost replaced the eye at the modern telescope, that is, in the big observatories where research work is being carried on, you will find that most of the big telescopes now going up are reflectors.

The silver film is the bugbear of the reflecting telescope, to the amateur at least. It is easy to see why this has been so, but it is not quite so plain why this should continue to be so. Nothing would further the cause of popular astronomy more and be a greater stimulus to telescope making by amateurs than the dissemination of plain and definite instructions in the matter of silvering, and positive assurances that successful work in this feature may be done by anyone without any chemical training or any elaborate equipment. Of course it will be said, "it is all right for chemists and those having a laboratory to do it with, to talk so." I do not fear to say that 99 per cent of the failures experienced in this work is because directions have not been followed to the letter —in the making of solutions, in manipulations and in cleanliness. The chemical deposition of metallic silver on a glass surface, from solutions of that metal, is one of the most beautiful and instructive experiments in the entire realm of chemistry, and in fascination is to be compared with the development of a photographic plate in a darkroom; and is not any more difficult. No formula where measures are given in *tablespoons*, or where *boiled water* is directed to be used, should ever be permitted to appear in print. And I should advise the amateur, that while experimenting to discover new and better ways of doing things is commendable, that he learn the old

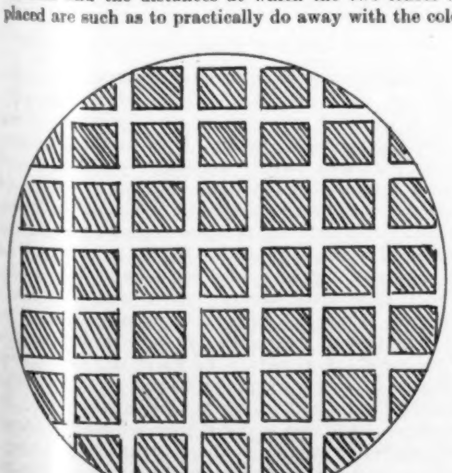


Fig. 11.—Polishing tool—normal

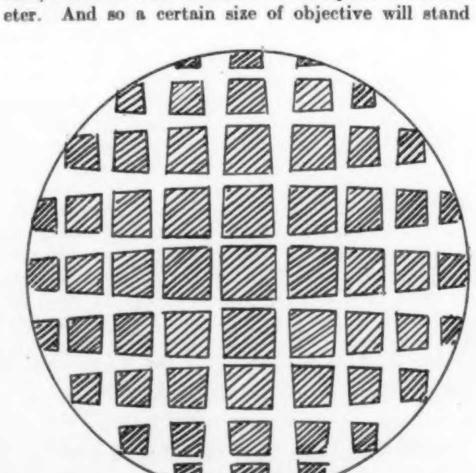


Fig. 12.—Polishing tool—parabolizing

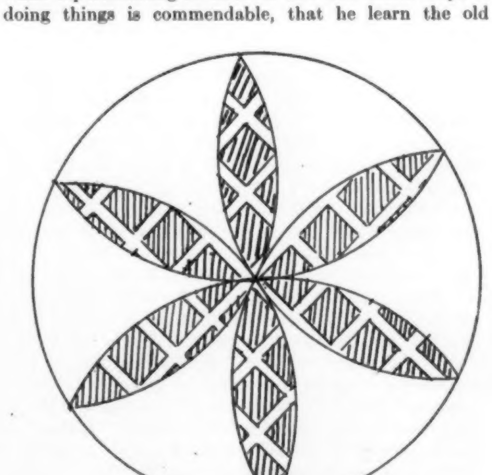


Fig. 13.—Polishing tool—six leaved

methods first, and to follow them to the letter. When he has succeeded in getting silver, as he will if he does thus, he can then experiment with modifications. When he knows that a chemist can analyze a solution of some sort, or a sample of drinking water, and report the amount of that substance in parts per million, because just so much of one chemical element will combine with, or be used by, just so much of another element, he will see why these solutions call for so and so many grains of a chemical in so many ounces of water, and not by the haphazard methods that serve in a recipe for mixing pancake batter.

To succeed in silvering one must observe three rules: cleanliness of the surface to be silvered, and of the graduates or utensils used for measuring and mixing the solutions; the use of distilled water only for solutions and in the final rinsing of surfaces; the temperatures of glass and solutions.

Unless one has graduates for measuring and fairly accurate balances for weighing (the ordinary darkroom equipment usually suffices) it is better to have the solutions made up by a pharmacist. And he must be instructed to observe the rules also, as in ordinary prescription work the need of chemical exaction is not so great, and many do not use distilled water in mixing medicines. Fresh, clean papers must be placed on the scale pans, the bottles for the solutions should be cleaned the same as the graduates, and the potash solution should be placed in a bottle with a glass or rubber stopper. The quantities indicated in the formula are sufficient for several 6-inch mirrors, and the beginner should practice silvering small pieces of plate glass, such as one would have left after cutting out a circle from a plate, any shape, and an inch or two or three inches in size. Small quantities of solution are mixed and used, and thus one can practice silvering these small pieces without wasting any great amount of solution. An ounce of the mixture (a quarter ounce of each of the four solutions) is all that is needed for a piece 1½-inch square. And so when one has learned to silver and burnish these small pieces to satisfaction he can approach with confidence the silvering of the speculum.

There are several methods of silvering and numerous formulae. Which of these is the best I cannot say. I should say that the best for beginners is the simplest one that yields results. There are complicated and involved methods that no doubt yield fine results in the hands of experts, but are impossible for beginners. The method I shall describe is certainly the most simple and definite I have known of, and I have obtained films that even an expert has judged "plenty good," only 2 per cent of the light being lost in reflection. When telescope users learn to do their own silvering and do it well, the reflector will be considered a better instrument than is the case now because no one would use a speculum with a tarnished surface. In comparing the two types of telescopes it will be found that the "light grasp" of a freshly silvered mirror is equal to that of an object glass of the same size, but of course a tarnished film will not perform so creditably. By keeping the caps over the mirrors when not in use, tarnish will often be prevented for an amazingly long time. But even if a mirror does gather the same amount of light, that is not saying that the reflecting telescope is equal aperture for aperture to the refractor, because the diagonal flat cuts off part of the light, usually about one-twentieth of the area of the speculum being thus out of commission. Right angled, internal reflecting prisms have been used in place of the silvered flat, but they are expensive, cannot be "home made," and at present the flat is more in evidence than ever.

Not infrequently one is asked if the placing of an object thus in the path of the light rays to the speculum does not affect the shape of the image; or, for instance, if its projection does not cause a shadow in the center of the moon if that body be viewed, or if a shadow, or "blind spot," be not present in the center of the field at all times. No. It may be said here that any obstruction of light rays cuts down the illumination, makes an image less bright; but unless that obstruction be in the focus of objective, speculum, or eyepiece, it will not be visible in any way. For instance, the cross wires in the finder will not be visible unless in the focus of objective, or eyepiece, and if you cover any part of an object glass, or stick a label of any shape on it, you will not see the label; but if it cover any considerable part of the glass it will have the effect of darkening the whole field. So the flat in the reflector, unless it be needlessly large, does not alter appreciably either definition or illumination. It is made elliptical and edges beveled, and the cell constructed so as to obstruct as little of the light as possible. The elliptical shape presents a circular projection on both speculum and eyepiece. If relatively large, and if of other than circular projection on mirror, it will in some ways affect images, but it is not necessary for us to further discuss it.

How does a star look in a telescope? Is it true that the larger the telescope the smaller a star appears? A star is so far away that no magnification will show an appreciable surface, the theoretical "point" of the geometer being all one should see. But telescopists speak of star "discs." Yes, and to our eyes the stars, and planets, too, appear "star" shaped. Both phenomena are caused by lack of perfection in eye and glass. If the star image were the theoretical point, we would not see it at all, as a point has no size. So the star disc is called a diffraction ring, or spurious disc, and peculiar as it may seem, the stronger the telescope the brighter the image and the smaller the disc—with any given magnification. But the diffraction rings are easily seen to be different from the real disc one sees in viewing a planet.

IV.—THE HISTORY OF THE REFLECTING TELESCOPE

Any one making or using a reflecting telescope will have his interest quickened by knowing something of the history of this instrument. The reflecting telescope will be forever linked with the illustrious names of Newton, the Herschells, Lassel and Rosse; and the significant chapter of its recent history that was written by the lamented Keeler is another gem in its already bright crown.

Gallileo was the first man to use a telescope of any kind in making astronomical observations, though it seems he was not the actual inventor. His telescopes were refractors, the first one magnifying three diameter. The glass with which he discovered Jupiter's satellites magnified 33 diameters. This is about the limit attainable in the way of magnification with simple non-achromatic lenses, and it was not until after Dolland's invention of the achromatic object glass, about 1757, that further progress was possible with refractors, and another half century passed before discs of flint glass of any size—over 4 or 5 inches—and of proper quality could be secured. So it was while the world was waiting for the achromatic telescope's development that the brilliant chapters of the reflector's history were written, the giant four-foot and six-foot reflectors in the hands of Herschell, Lassel and Rosse forcing the heavens to yield some of their deepest secrets. And who would wish to overlook the touching incidents of Catherine Herschell's devotion to her brother, feeding him out of her own hands while he ground and polished unceasingly at his big speculum, and standing at his side to record his observations when the temperature was such as to freeze the ink in the bottle.

So it was the reflecting telescope that made possible the Augustan era of astronomical discovery from Newton to Rosse, and while it had to yield temporarily to the refractor during the half century from Fraunhofer to Clark and Brashear, it is again in the ascendency because of its superior qualifications as a photographic and spectographic instrument. Nearly all the big telescopes going up in all parts of the world today are reflectors, the 72-inch Dominion, the 70-inch Cordoba, and the Mount Wilson 100-inch.

Unkind things have been said about the modern big telescope with the research expert and the photographic plate at the eye end of it. But while the education of the people in astronomical matters, and by means of numerous small and medium sized instruments, is an objective for which all true lovers of the science are striving, we must keep up the research. And there is no reason why the amateur cannot resort to the photographic plate. When he has gotten his instrument working and has become familiar with the observational work he will find new thrills in the workings of the photographic plate. While the retina of the eye fatigues after a few seconds of intensive peering, the unemotional and untiring glass plate will record the cumulative effect of several hours of action of a ray of light, and with any given instrument photography will show up things that no human eye would ever see in that same instrument. The giant photographic telescopes of today are revealing stars so distant and so faint that no human eye will ever see them directly in any telescope that ever was or ever will be built. But the big telescope and the glass plate has restored some measures of confidence and assurance to us mortals by showing us the *beginning* of the *limit* to the universe. It was disconcerting to find that with every increase in telescopic power, and every improvement in such auxiliary aids as photographic and spectographic appliances, the ever increasing depths of space thus penetrated were found to contain stars and stars and stars. But a change has come and the giant telescope with the photographic plate and the research expert has rendered the service of showing that there is actually a visible thinning out of the stars within the range of the present space piercing appliances.

V.—EYEPIECES

The three optical parts of the reflecting telescope are the speculum, flat and the eyepiece. Before taking up the making and silvering of the speculum and flat, we shall discuss eyepieces.

It is not practicable for the amateur to make his own eyepieces, in fact they may be purchased at a price that renders it unprofitable to make them. He would have to buy the lenses, and their mounting and proper centering is rather difficult work for the amateur.

The simplest eyepiece is a single convex lens, but vision is distinct only through a small, central area, the spherical aberration becoming very pronounced as one gets farther away from the center. If the reader has taken apart a spyglass he may have noticed that the eyepiece has fours lenses. In this "terrestrial" type, two of the lenses are needed to reinvert the image, thus making objects appear right side up; but in astronomical or celestial oculars the image being inverted is no objection, so this type has two lenses. By having the lenses a certain distance apart, and of certain curvatures, vision is distinct to the edge of the field, and the color correction is almost perfect.

The average price of celestial eyepieces is \$5. But the amateur may get a good eyepiece for \$1.50, if he will get those made for microscopes. They are of good quality, but smaller as a rule, and not made in very high magnifications. The outside diameter is a little less than an inch. The focal length is given in inches of "equivalent focus," as "1½ e. f.," or "e. f. 1 inch," and the "e. f." length is the same as a single lens of the same focus. These oculars are sometimes marked "5 X," or "10 X," which means that if used as magnifiers they magnify that amount. A 5X is e. f. 2-inch. A 10X is e. f. 1 inch. If such e. f. lengths are expressed in millimeters, the first would be 50mm., while the latter e. f. would be designated 25mm. The strongest microscope eyepiece is usually about ⅘-inch which with our mirror of 60 in focus, would yield a magnification of 75 diameters. I mention these eyepieces because they are inexpensive, and for the low magnifications they are very satisfactory. If the amateur gets two of these, say 1½ inch and ⅘ inch, he will secure magnifications of 40 and 75 diameters respectively, and after he gets familiar with the telescope and wishes higher powers, he may get one or two celestial oculars, of perhaps ½ in e. f. and ¼ in e. f., these yielding magnifications of 120 and 240 diameters with our reflector of 60 inch focus.

One must not underestimate the importance of having good eyepieces. And as they are comparatively cheap, it is certainly not wise for the amateur to try to make his own eyepieces. For the finder, one may wish to have cross wires in the focus of the ocular, and in the negative type these must be between the two lenses, while with positive oculars the wires or cross threads must be in front of the combination. An eyepiece can be used equally well in reflectors and refractors. One should know his eyepieces and always focus very carefully for his own individual eye. Some always crowd on the highest magnification that the telescope will stand. Groups and clusters that are beautiful beyond all description with low powers, lose their beauty when high magnifications are used.

The Newtonian reflector, Fig. 2, is the only one using a diagonal flat, and as the flat can be made by the amateur, while the convex "hyperboloidal" mirror used in the Cassegrainian type is beyond the beginner in instrument building, he had better stick to the Newtonian form. In Fig. 3 the Cassegrainian type is shown for the benefit of those who may be unfamiliar with its arrangement. The convex mirror reflects the light back through a hole in the center of the speculum, and the eyepiece is thus placed in a position like that of the refractor, and the observer looks in the same direction as he would in using a refractor. This form is becoming very popular for spectographic work, and some of the largest telescopes now going up in different parts of the world are Cassegrainian reflectors.

VI.—GRINDING AND POLISHING THE SPECULUM

As the object glass is the most important part of the refractor, and the costliest, so in the reflector the speculum is the vital part. In its construction one should exercise the greatest concern. Discs for the purpose are to be purchased, but the amateur would probably experience trouble in obtaining one, and it would cost somewhat. He would be ahead if he bought the finished article, rather than buy the glass made for that purpose, in a small size like six inches. He can usually get a disc of plate glass in some "art glass" works. They salvage broken plate glass windows, and a circle cut from a fragment should not cost much. The thickness is not so important in these sizes. In large instruments it is very important to have a thickness that will prevent changes in shape when the telescope is in different positions and that thickness is usually from ⅙ to $\frac{1}{10}$ the diameter. And then weighted levers are needed to secure the utmost inflexibility of shape, these levers causing a uniform pressure under all parts of the mirror. The six-foot mirror of the Dominion Observatory is a foot thick and weighs tons. But a six-inch disk of plate glass will be

stiff enough if of $\frac{1}{2}$-inch thickness, or even $\frac{3}{8}$-inch. Even thinner glass might do if the thicker cannot be gotten, but if nothing more than $\frac{5}{16}$ or $\frac{1}{4}$ inch is obtainable it would be better to make it into a five-inch mirror.

If you are to cut the circle yourself, get an ordinary 10-cent glass cutter, draw a circle on the glass with the cutter, using any circular object as a guide, and then make cuts across corners all over, but none of these cuts should go inside the circle. Hold the plate at the edge of a bench or any wooden object, with the scoring made with the cutter on the very edge, give it a quick but careful blow, and the fragment will break off nicely. Breaking off corners this way, all around, the plate finally becomes nearly round, and further work with a pair of pliers will get it down pretty close to the circle made with the cutter. The edge can be carefully treated with a grindstone, and a very neat disc results. It is advisable to practise at this work with any extra material one has, and soon you will find you can do a very good piece of work.

Make another disk for use as a "tool," of the same material, or it may be somewhat thinner, even down to $\frac{1}{4}$ inch. Cement this with pitch to the top of a post or the corner of a bench, so that you can walk around it as you are grinding. Take a large empty spool or a piece of wood curtain pole, two or three inches long, and cement it with pitch to the center of the speculum. It makes a very good handle for holding the disc.

It may seem needless to explain how and why one thus gets a concaved disc from rubbing two glasses together with emery powder between them. But one's interest is heightened in any work if the why and wherefore are known. Refer to the cuts and it will be seen why the speculum becomes hollowed out while the glass tool gets worn down on the edges. Whether a straight stroke is used or a circular one, it is seen that the center of the upper disc is never off the edge of the lower one, and consequently it is always being worn down, while most of the edge is nearly always off the tool, and then one gets all the graduations of grinding between the two extremes. The longer the stroke the more the center is ground in proportion to the other portions. If a very short stroke is used, either the straight or circular, a larger central part of the speculum is always on the tool underneath, and the small central area that was ground so much more than the other parts when the long stroke was used, is ground less in proportion to other parts with a short stroke.

In a similar manner we can understand why the tool is worn down on the edges and very little or none in the center. In Fig. 9 (a), the light solid circle represents the circumference of the tool, and the heavy solid line the outline of the speculum. If a circular stroke is used, and the speculum swung in a circle represented by the light dotted line, the center of the speculum and the edge of the tool get the greater part of the ebrading effect. Fig. 9 (b) and (c) indicate different positions of the speculum in its swing in the circular stroke. If the glass discs are rather thin, and therefore one wishes no unnecessary wearing down of the whole surface, of which there will be some, of course, it is considered better to use the circular stroke. The writer has found the circular motion best in the rough grinding, a combination of the two in fine grinding, and the straight in the polishing.

Let us now consider the grinding. The big mirrors, the five and six-foot ones, are ground by power, but for discs under a foot, hand work is generally used. Emery powder is graded so differently that one can follow no particular rule in purchasing it. Some style a grade as "medium" that another sells as fine, or perhaps as coarse. I obtained three grades, coarse, medium and fine; but I after regretted using the coarse as it was so coarse that it left pits that were very hard to get out with the succeeding grade. And for as small a glass as six inches, the little extra time consumed in using a little finer powder is negligible. Fine sand such as one finds on a sand beach may be used first. Cement the glass tool to the top of a post or some object so that you may go around it, place on it a teaspoonful of medium emery powder, wet it and place the speculum thereon, push it back and forth over the tool, turning it a little for every stroke, and yourself walking slowly around the post on which your work is being done. So there are three motions to be performed. The straight stroke over the tool, the rotating or turning of the speculum about its own center with every separate stroke, and your own motion around the tool, the last two motions being to prevent either disc from being worn into a groove. If you use a circular stroke, you must also perform these last two movements, but it must not be swung in a true circle, but a little to one side and a little to the other side so as to prevent the tool from getting worn into rings. The motions must be irregular, no two strokes in the same place being allowed. After a time you will observe that the disk is getting hollowed out.

After a while test the figure and focus. To do this wash off the emery and while the glass is wet hold it up to the sun. Tilt it so the reflection falls on the doorframe, or on any convenient object, and note where the image of the sun is smallest and most distinct. When this is about five feet, or a little more, the rough grinding may be discontinued.

Fine grinding and polishing remain. Get two or three pounds of emery "flour." Prepare six jars, one of which at least should be of about a gallon or three-quart capacity. They must be clean. Label them Nos. 1, 2, 3, 4, 5 and 6. Place the emery flour in jar No. 1. Nearly fill it with water. Stir it well with a clean rod or stick, then let it settle for twenty minutes. Quickly but carefully pour off the upper two-thirds of the contents into jar 2. Add some water to jar 2 until it is nearly full. Stir it well and then let it settle for one minute. Pour off the upper two-thirds of its contents into jar No. 3. Add water to this poured off part which is in jar 3, to nearly fill it, stir as before, let settle three minutes, pour off upper portion into jar 4. Add water to this suspension in jar 4 to nearly fill it, stir as before and then let settle seven minutes. Pour off upper portion of this into jar 5. Add water to 5, stir, let stand 20 minutes, pour off upper portion into jar No. 6. Add water, stir, let stand for 60 minutes, pour off upper part, which is hardly anything but water. Discard the poured off part, and the finest flour is left in jar 6. It is "60, minute" flour, because it is the size of particles that took 60 minutes to settle out of the suspension. Each of these jars are allowed to stand for some time until clear water is on top, and this can best be siphoned off. The wet paste can be used as it is, or if let stand so that water dries out and leaves dry powder, you can place the powder on the glass tool and moisten it as used. Be very careful not to get any of one grade spilled or mixed into another of the grades. You grind with grade 1 for 10 or 15 minutes, then with No. 2, and so on until you get to No. 6, after which you will find the glass in a very smooth condition. Examine the glass very carefully after grinding with each grade, and if any pits remain, continue grinding with that grade until such pits or cuts are out. If you do not observe this precaution you may find for instance that when you have worked with grade 5 or 6, and the glass is coming down to a beautifully smooth condition, that you have a few ugly pits or cuts left from the rough grinding or from grinding with grades 1 or 2. The same strokes may be used in fine grinding that were used in rough grinding. If the emery flour is properly graded into the six different degrees of fineness, and the grinding done according to the instructions, the surface will be found in a very fine condition after No. 6, in fact in an almost polished condition.

Now then for polishing and "parabolizing." After the grinding the surface of the glass is a section of sphere. But a spherical surface will, in either a lens or a mirror, not do. "Spherical aberration" will interfere with the perfection of the image. A true parabolic surface is needed, and as far as possible must be attained. But in a six-inch mirror of five or six-foot focus, the amount of glass that must be ground off to approximate the parabolic figure is slight, and is accomplished in the polishing.

The glass tool on which the grinding has been done, both rough and fine grinding, cannot be used in polishing except it be covered with some plastic substance such as pitch. Most writers will tell the amateur telescope maker to melt some pitch and pour it on the glass tool. Then when he goes to buy pitch (or tar) he will find it already of a consistency about equal to that of cream. What he should do, unless he succeeds in finding pitch of a consistency that I have never yet been able to find, is to get some yellow beeswax, and melt some of it and mix into some of the almost liquid pitch, usually about 10 or 20 parts wax in 100 of pitch. It may need more or it may need less wax, but the rule is to add enough wax to make the mixture about as hard as butter or cheese—that is at ordinary temperatures, and it can be softened and liquified by heating. It can be cut with a knife wet with soap water. Melt it enough to pour onto the plate, and before it has hardened completely, press the mirror surface down upon it, having first wet the glass with soap water to prevent sticking. This imprint of the glass leaves a surface matching that of the glass. Trim off the pitch at the edges of the disc, and prepare your rouge, and you are ready for polishing.

Get a $\frac{1}{2}$-pound of the finest jewellers rouge. It is cheap, being nothing but oxide of iron. In the average town it may be hard to get, often the drug stores do not stock it, and some jeweller will have an ounce or so on hand, and perhaps none. Send to some apparatus and chemical concern, for instance some firm selling high school laboratory apparatus, and you will save time and trouble. But do not use it as it is. It is liable to contain some grit particles that will scratch the surface, so submit it to "washing," or water separation as you did with the emery flour, only you need not separate into different grades. Do as follows: place some of it in a tall, narrow container (a tall narrow preserve jar, or a large test tube). Add water and shake it thoroughly, and then let it settle for $\frac{1}{2}$ hour, carefully siphon or draw off in some way the water at the top, and then the upper layers of this paste may be removed with a clean spoon, or if it has stood long enough for the water to dry out, the upper layers of the powder may be taken out; but in either case do not disturb the lower layers because any grit that may have been present will have settled to the bottom layers of the sediment. It is important to carefully wash the rouge in this way, as you will also use rouge for burnishing the silver film as well as for polishing the glass after grinding.

As previously stated a straight or circular stroke may be used in grinding, but in polishing a straight movement is often preferred, though what is thus styled straight is not quite so, as the disc is swung slightly first to one side and then to the other in the back and forth motions. The squares, or facets, are gradually pressed down and would be obliterated in a time if not renewed. The pitch is remelted and a new pad formed and pressed into the shape of the mirror by pressing down with the soapwater moistened mirror surface. New grooves of the desired width and shape are cut, and rouge paste again applied. Thus one continues until the glass surface is perfectly polished. New grooves and squares may be formed by retracing or recutting the grooves in the pitch pad, but without remelting and recasting of the pitch if the pad is otherwise in good shape. See that no shreds of pitch protrude from the edges of the grooves. They will stick to the glass and cause trouble. All parts of the polisher should be thoroughly covered with the rouge paste.

At any time pitch may get onto the glass, or onto any tool or object, it is best removed with chloroform or turpentine.

For very small specula the whirling motion is sometimes used in polishing. The disc is spun or whirled around on the polisher. The handle cemented to the disc is twirled between the thumb and fingers. But if this motion is used the disc must not be spun on one part of the polisher for any length of time, but must be worked around irregularly so as to avoid being worn in rings.

Do not let the term "polisher" confuse you. The polisher is simply the glass tool that was used in grinding, but which now has been covered by the layer of pitch. The pitch being usually too thin to use as it is we melted it and added melted beeswax, the resulting mixture when cold being of about the consistency of hard butter, or perhaps cheese. Then too some apply a thin coat of beeswax over the layer of pitch, applying it with a brush while in a melted condition. It usually imparts a finer surface to the glass. But do not confuse this layer of wax with the wax that was mixed with the pitch. The wax mixed with the pitch was melted in with it to make it of the proper consistency for using as a pad on top of the glass tool. But as stated many prefer to add a thin layer of *wax alone* on top of the pad of congealed pitch-wax.

Grooves are cut or traced with some suitable object—the point of a knife blade or the end of a stick that has been fashioned to a point, in a criss cross manner over the surface of the polisher. If these are cut so that the intervening squares are all of the same size, all parts of the polisher will have the same effect, and the mirror will be polished to the same extent, and such a polisher may be styled a "normal" polishing tool. If the grooves are wider towards the edges of the tool, and thus the squares are smaller in those parts, it will have the effect of wearing down the center proportionately more than the parts nearer the edge, and thus tend to produce an approximate parabolic figure. The six-leaved polisher shown in Fig. 13 will have the same effect, or nearly so. To make such a polisher the entire surface of the tool may be covered with pitch and grooves of even width cut all over it, then trace out the six-leaved figure and cut and pare away all parts except the six leaves, and this form serves well except that the configuration has to be remade oftener than the other type of parabolizing tool.

It is better to apply the rouge to the surface of the polisher in a paste form, and it will be recalled that in washing, or "water separating" the rouge, the upper layers were to be removed without disturbing the lower layer, as it would contain the grit particles which had settled to the bottom. If the rouge were no tused while still moist, but had dried, it must be remade into a paste and applied to the pitch squares with a flat, thin brush. The creamy, frothy upper layers contain only the finest rouge and produces the most beautiful polish of the mirror surface, but a little more time may be consumed polishing with this fine rouge, but it will be time well spent.

The parabolizing must be done in polishing, and is accomplished by regulating the size of the pitch squares. Fig. 11 shows a polisher with squares of equal size, and as this polisher has a surface of the same shape as the speculum, it would polish the speculum but not alter its shape. Now a parabolic curve is produced by wearing down the glass *proportionately* more in the center, and a polisher with larger squares in the central parts will bring that about. The grooves in the pitch surface are wider towards the edges of the polisher, and the wider the grooves the smaller the squares. Or the six-leaved polisher may at times be used. The Foucalt knife edge test shows up the zones or rings that are either above or below the average of the surface, and then polishers may be fashioned to wear down the protruberant zones, or if a ring or zone is already too deep, a polisher shaped to wear down the whole surface except that zone. This test is briefly described further on, and every amateur should learn this test and how to make the corrections indicated by it.

[TO BE CONTINUED]

The Art of Living*

In his first presidential address before the Institution of Mechanical Engineers Dr. Unwin quoted a saying of Samuel Butler to the effect that life is the art of drawing sufficient conclusions from insufficient premises. He then went on to apply this idea to the work of engineers, recalling the fact that in the solution of engineering problems there are always many factors which are incompletely known, and about which it is necessary to make assumptions which in some cases are really guesses. Butler's aphorism, however, is far from being a complete statement of the case. The drawing of conclusions, however sufficient, is not life, since life, for practical purposes, implies motion or action of some kind. In certain subjects, for instance in philosophy, it is not possible to give effect to conclusions, and all that they lead to is a sense of satisfaction at having settled some doubtful question and freed the mind from the worry of uncertainty. They may thus set the energies at liberty to expend themselves in other directions. The same result is, however, sometimes attained by ignoring all problems that do not lead to results which can be subjected to experimental verification, and this is vastly simpler. Professor Huxley took this attitude when he invented the term agnostic for himself and refused to yield to the custom of drawing conclusions from insufficient data in cases in which it was not possible to subject these conclusions to the test of experience. He is not likely to have many followers, for the human mind demands explanations of phenomena, and also of its fears and hopes. Astrologers and medicine men have thriven on this demand ever since the race existed, and will continue to do so. Already the word agnostic has almost lost its original meaning and is applied to those who have arrived at conclusions which are not generally considered orthodox.

It is instructive to notice Butler's choice of words. He does not say correct conclusions, but sufficient conclusions, and we know by experience that wonderful results can be attained by conclusions that are manifestly incorrect. The Chrstian Scientists have arrived, from premises that seem insufficient to most of us, at the conclusion that pain has no existence, and is only subjective. Some of them seem to be able to conduct their lives according to this conclusion, and to go about with smiling faces when evidently suffering from diseases which would lay other people aside. This suggests that the accuracy of conclusions is far less important than the sincerity with which they are held and the courage with which they are applied. Certainly there is much truth in this view as regards engineering problems. We do not suggest that success can be obtained from utterly fallacious conclusions, but it is quite certain that "sufficient conclusions" are useless unless they are held by a man who has the courage to bear the responsibility of advising his clients to risk their money in putting them into concrete form, and who at the same time has the faculty of inspiring confidence in his abilities. Many important designs, involving much skill and not a little mechanical instinct (as distinct from engineering knowledge), are got out by draughtsmen who are utterly incapable of carrying them into execution, except so far as drawings may be considered a stage in execution. They can arrive at sufficient conclusions from insufficient premises, but there they stick. Their work represents to them a balance of probabilities, but they are never certain that they have weighed each probability correctly. They know that they have done their best, but they are by no means certain that mistake has not crept in somewhere, and they have not the courage to go forward as if their plan were based on certitudes. What they need to do is, metaphorically, to burn their boats, trusting to their abilities to fight or outflank each difficulty as it is encountered, and this they have not the courage to do. They have not mastered the art of living in a complete sense.

Life does not consist so much in drawing conclusions as in acting upon them. It is colored by the sufficiency or otherwise of the conclusions, but whatever that may be, the life may still be virile. Courage, resource and initiative are the qualities that enable a man to fill a great part in the world. When they are combined with the faculty of drawing sufficient conclusions from insufficient premises we have a Napoleon, the man who can discover opportunities, or create them if they do not exist. The great thing is that a man have the courage to do something, to enter into the conflict with Nature and attempt to direct her forces into hitherto unattempted channels. Sometimes they will refuse his guidance, and then he will need to take comfort from the proverb "He who has never made a mistake has achieved nothing."

The mention of Napoleon recalls the fact that it is in military affairs that the faculty of forming sufficient conclusions from insufficient premises counts most. Wellington was once driving with a friend through an unfamiliar country, and the two amused themselves by guessing what they would find beyond each turn of the road. Wellington was by far the most successful of the two, and explained the fact by saying that a great part of his life had been passed in guessing what was hapening "on the other side of the hill." The construction of the lines at Torres Vedras shows that he guessed rightly that his opponent would drive him back to the sea, while it also demonstrates that Massena never anticipated that Wellington had constructed an impregnable fortress into which to retreat. On the other hand, Wellington made a bad guess when he kept 18,000 men on the Mons road during the battle of Waterloo, on the assumption that Napoleon would endeavor to turn his right flank. Those men would have been very useful in the battle, and would have rendered Wellington much less dependent on Blucher's aid. However, he won the day, and this was what he set out to do.

The engineer, unlike the military man, does not guess in competition with an opponent like himself. He guesses against Nature, and although this is a redoubtable antagonist it, at any rate, plays no tricks. Under uniform conditions its action is uniform. Unfortunately conditions are very seldom uniform, and it is often quite impossible to determine beforehand either what they are, or how they will affect other and calculable forces of which they will form the environment. Often it is quite impossible to draw conclusions very far ahead. The work must be commenced in a tentative fashion, akin to the surgeon's exploratory incision, and data must be sought as a proceeds. This is research work on an heroic scale, and needs not only skill and initiative, but immense courage and self-confidence. It also involves great anxiety and a load of responsibility which only a strong man can carry. Strength is the product of effort; it grows the more it is exercised. But there are limits peculiar to each individual; it is not everyone that is born with the possibility of becoming a Samson, even with the most constant effort. We do not for one moment suggest that the art of living is a sealed book to such men. They can, and often do, carry the full load of responsibility which their mental physique will permit, and perform most useful work in the world. Sir Maurice Fitzmaurice, in his presidential address before the Institution of Civil Engineers last November, bore generous testimony to the value of subordinates who perform their duty conscientiously and loyally, and he incidentally hinted that the resident engineer may live a happier and pleasanter life than his chief, even though the latter may be looking forward to filling the presidential chair.

In that remarkable series of articles on the war which appeared in the *Spectator* under the name of "A Student in Arms," there appears the following statement: "To know one's limitations is a mark of wisdom; to rest content with them merits contempt. There is no dishonor in a humble lot—unless one is shirking the responsibilities of one more exalted." This sums up the whole matter of the art of living. Each needs to live as fully as he can, but never to be satisfied that he has attained to his complete development. If he can draw sufficient conclusions on a certain subject and can put them on paper he has accomplished a good deal, even if he cannot carry them forward into concrete form. He has, at any rate, released someone of stronger fiber to do the rougher and more adventurous part of the work, just as the woman munition worker contributes something to the perilous duty of the trenches when she undertakes a man's task at the lathe. Some day the humble worker may develop greater strength, and so make progress in the art of living. So long as he is not satisfied that his conclusions shall be merely "sufficient," and strives to attain closer and closer approximation to exactitude even on paper, without attempting the more perilous problem of putting them into concrete form, he displays the fruits of vitality. Of course we are writing as engineers. To us material matters are of high importance, but we must never forget that mankind, in spite of its animal instincts, never fails in the long run to rank spirit above matter.

*Engineering.

Photographic Color Prints on Silk

The Manufacture Nationale des Gobelins has recently adopted the process of Messrs. Vallette and Féret for photographic color printing. Impressions are made in blue, yellow and red. The precision required in the superposition of the three impressions is secured by means of a special frame on which the article is stretched with the aid of metallic eyelets. The sensitizers used are alkaline phenols and diazo sulphites, and the colors are developed by exposure to the electric light.—*Engineering.*

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